

**SINGLE STAGE EXPERIMENTAL EVALUATION  
OF  
SLOTTED ROTOR AND STATOR BLADING  
PART II - ANNULAR CASCADE INVESTIGATION  
OF SLOT LOCATION AND GEOMETRY**

**PREPARED FOR  
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
CONTRACT NAS3-7603  
31 OCTOBER 1966**

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N66-39939

## ABSTRACT

An annular cascade investigation was conducted to provide criteria for the design of slotted rotors and stators to be tested in a subsequent part of the overall program. The test stators were 65-series airfoils, having a chord length of 6.5 inches and a calculated midspan D-factor loading of 0.528 without slots. A slot located approximately midway between the point of minimum pressure and the point of separation produced the best performance, reducing the wake loss coefficient to about 17% of that for the unslotted vane and increasing the lift coefficient and air turning angle approximately 10% and 2 degrees, respectively.

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## CONTENTS

SECTION		PAGE
	ILLUSTRATIONS . . . . .	iv
I	SUMMARY . . . . .	I-1
II	INTRODUCTION . . . . .	II-1
III	TEST EQUIPMENT . . . . .	III-1
	A. Test Facility . . . . .	III-1
	B. Compressor Test Rig . . . . .	III-1
	C. Inlet Guide Vane Design . . . . .	III-2
	D. Stator Design . . . . .	III-2
	E. Instrumentation . . . . .	III-3
IV	PROCEDURES . . . . .	IV-1
	A. Test Procedure . . . . .	IV-1
	B. Data Reduction Procedure . . . . .	IV-2
V	RESULTS AND DISCUSSION . . . . .	V-1
	A. Unslotted Stator Vane Performance . . . . .	V-1
	B. Slot Configuration Selection . . . . .	V-4
	C. Slotted Stator Vane Performance . . . . .	V-5
VI	CONCLUDING REMARKS . . . . .	VI-1
	A. Effect of Slot Location on Performance . . . . .	VI-1
	B. Effect of Slot Geometry on Performance . . . . .	VI-2
	APPENDIX A - List of Symbols . . . . .	A-1
	APPENDIX B - Tabulated Data . . . . .	B-1
	APPENDIX C - Bibliography . . . . .	C-1
	APPENDIX D - Illustrations . . . . .	D-1

## ILLUSTRATIONS

FIGURE		PAGE
III-1	Schematic of the Compressor Research Facility. . . . .	D-2
III-2	Compressor Research Facility . . . . .	D-3
III-3	Schematic of Annular Cascade Rig . . . . .	D-4
III-4	Stator Vane Assembly . . . . .	D-5
III-5	Test Section Instrumentation Layout. . . . .	D-6
III-6	Instrumentation, Plenum Chamber and Stations 1, 2, and 3A (View Looking Downstream) . . . . .	D-7
III-7	Stator Surface Pressure Tap Locations. . . . .	D-8
III-8	Static Pressure Tap Locations Near Forward Slot. . . . .	D-9
III-9	Static Pressure Tap Locations Near Rear Slot . . . . .	D-10
III-10	Static Pressure Tap Installation . . . . .	D-11
III-11	Total Pressure Probes. . . . .	D-12
IV-1	Circumferential Static Pressure Deviation at Station 3A (Forward Slot Configurations) . . . . .	D-13
IV-2	Circumferential Static Pressure Deviation at Station 3A (Rear Slot Configurations). . . . .	D-14
V-1	IBM Plot of Stator Inlet Air Angle Profile, Configuration 1, Station 2 . . . . .	D-15
V-2	Typical Inlet Guide Vane Wake Total Pressure Profile. . . . .	D-16
V-3	Variation of Static Pressure Coefficient for Unslotted Stator Vane. . . . .	D-17
V-4	Dye Injection Pattern, Unslotted Configuration . . . . .	D-18
V-5	Unslotted Stator Wake Total Pressure Profile . . . . .	D-19
V-6	Variation of Total Pressure Loss Parameter With Diffusion Factor (Unslotted Stators) . . . . .	D-20
V-7	Slot Geometry Nomenclature and Parameters. . . . .	D-21
V-8	Annular Cascade Stator Slot Configurations . . . . .	D-22
V-9	Annular Cascade Stator Slot Configurations . . . . .	D-23
V-10	Comparison Unslotted Stator Wake With Forward Slot Stator Wake . . . . .	D-24
V-11	Comparison of Unslotted Stator Wake With Rear Slot Stator Wake . . . . .	D-25
V-12	Variation of Total Pressure Loss Parameter With Diffusion Factor (All Configurations). . . . .	D-26

## ILLUSTRATIONS (Continued)

FIGURE		PAGE
V-13	Variation of Static Pressure Coefficient for Slotted Stator (Configuration 9). . . . .	D-27
V-14	Variation of Static Pressure Coefficient for Slotted Stator (Configuration 4). . . . .	D-28
V-15	IBM Plot of Stator Exit Air Angle Profile, Configuration 9, Station 3A . . . . .	D-29

SECTION I  
SUMMARY

An annular cascade investigation was conducted to provide criteria for the design of slotted rotors and stators to be tested in a subsequent part of the overall program. The test stators were 65-series airfoils, having a chord length of 6.5 inches and a calculated midspan D-factor loading of 0.528 without slots. The tests were conducted at an inlet Mach number of 0.64.

Initial tests of the unslotted stator disclosed that the minimum pressure and separation points occurred at 12 and 85% of the chord, respectively. Based on these data, two axial slot locations were selected. The forward location was at 55% of the chord on the suction surface, which was approximately halfway between the minimum pressure point and the flow separation point. The rearward point was selected at 75% of the chord, which was slightly ahead of the flow separation point for the unslotted configuration. In addition to slot location, several variations of slot geometry were tested at each slot location.

For the forward slot location, the stator wake loss coefficient varied between 17 and 43% of the unslotted loss coefficient, depending on the slot geometry utilized. For the rearward location, the loss coefficient ranged between 76 and 187% of the unslotted loss coefficient, depending on the slot geometry employed. Data for both slot locations indicated about the same increases in lift coefficient and air turning angle. The slot configuration with the lowest wake loss coefficient showed increases in lift coefficient and turning angle of about 10% and 2 degrees, respectively.

## SECTION II INTRODUCTION

Significant advancements in compressor technology require (1) advanced rotor and stator concepts in terms of improved blading for high flow Mach numbers, (2) high lift devices for stators and rotors, and (3) a more adjustable geometry to extend the stall-free flow range. Progress in any of these areas may result in a sizable reduction in the number of compressor stages required for any specific application, and an improved compressor.

Pratt & Whitney Aircraft is engaged in a program under NASA Contract NAS3-7603 to investigate the application of high lift devices (in the form of slots) to subsonic rotors and stators. A systematic investigation of slots will be made to establish the feasibility and extent to which slotted blade concepts can be used to increase allowable blade loadings and the stable operating range of compressor stages. To accomplish this objective, three stator blade rows and three rotor blade rows will be built and tested. Tests with stators will use a representative state-of-the-art rotor to generate the stator inlet flow.

A survey of the literature on slotted airfoils was conducted to determine if any design information applicable to compressor blading existed. A bibliography is presented in Appendix C. The results of this survey showed that, whereas much data exist for isolated airfoils at low Mach numbers, slot design criteria applicable to high speed cascades are not available. It was therefore proposed, as part of the contract design effort, to conduct a series of annular cascade tests with slotted stators to establish preliminary criteria for the design of the slotted rotors and stators for the rotating stage test program.

A set of high turning inlet guide vanes was used to establish the whirl distribution into the stator test blade row of the annular cascade. These guide vanes were designed to produce essentially a constant flow angle from hub to tip for the 0.8 hub-tip ratio test vehicle. The test stator had a constant section from root to tip and had no twist. Initial tests were conducted with the unslotted stator blades to obtain their pressure distribution and flow separation point. On the basis of these

tests, two chordwise slot locations were chosen, and a range of slot geometries was investigated for each location. Because of the preliminary nature of these tests, only mean radius data were obtained for essentially one flow condition, angle of attack, and Mach number. Selection of the best slot location and geometry was based on wake loss, integrated lift coefficient, and cascade turning. This report presents the details of the test equipment, procedures, and test results for this preliminary annular cascade study.



### SECTION III TEST EQUIPMENT

#### A. TEST FACILITY

The annular cascade tests were conducted in the compressor research facility shown in figures III-1 and III-2.\* In the nonrotating mode of operation, a J75 engine is used in conjunction with a two-stage ejector system to draw ambient air through the compressor rig. Flow rates up to approximately 110 lb/sec are possible at atmospheric inlet pressure. Ambient air enters the compressor test rig through a 78-foot inlet duct, plenum chamber, and bellmouth inlet and exhausts through the ejector system. Airflow rate is measured by means of an ASME thin plate orifice located in the inlet duct. The plenum chamber is sufficiently large to provide essentially stagnation conditions upstream of the bellmouth inlet to the test rig, and a long diffuser ahead of the plenum ensures uniform conditions across the chamber.

The inlet duct and plenum chamber are mounted on a track and can be rolled away from the test rig. A pneumatic tube seal is used to prevent air leakage between the plenum chamber and test rig.

#### B. COMPRESSOR TEST RIG

The compressor test rig consisted of a bellmouth inlet, support struts, inlet guide vanes, test stators, and an exhaust diffuser section, as shown schematically in figure III-3. Inner and outer wall diameters at axial stations of interest are tabulated in the figure. The desired gas path was formed by fabricated wooden filler sections. A split test case provided convenient accessibility for blading changes without removing the entire rig from the test stand.

The test section had a hub/tip ratio of approximately 0.8, and was comprised of a row of 50 inlet guide vanes that set the stator inlet conditions and a row of 20 test stators that turned the flow back to the near-axial direction. The inlet guide vane and stator blade row assemblies were each divided into two 180-degree sections. The guide vanes were fabricated from stainless steel and tack-welded to the shrouds. The stator and stator

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\*Figures are presented in Appendix D.

shrouds were fabricated from aluminum and the stators were positioned with dowel pins and held in place with machine screws, as shown in figure III-4. For the slotted stator tests, only the vanes in the upper 180-degree section were slotted.

#### C. INLET GUIDE VANE DESIGN

The inlet guide vanes were designed for a constant turning of 50.4 degrees. NACA series 63 blade sections were chosen for this blade row. Details of this design are listed in table III-1.

#### D. STATOR DESIGN

Selection of the stator configuration for slot evaluation was based on the criterion that the stator should be typical of the blading geometry to be used in the rotating phase of the program. The 65-series airfoil section was selected for the stator vane profile (NACA 65-(16)09). A vane chord of 6.5 inches was chosen to permit the installation of sufficient static pressure instrumentation, and to provide a large scale model that would allow accurate determination of the effect of small changes in slot geometry.

The stator vane had a constant equivalent circular arc camber of 38.85 degrees from the hub to the tip and was untwisted. The loading (D-factor) distribution from hub to tip was 0.55 to 0.50 with a value of 0.528 at the mean radius. The inlet Mach number varied from 0.67 at the hub to 0.61 at the tip with a mean radius value of 0.637. Other details of the stator design are given in table III-1.

Table III-1. Summary of Design Data For The  
Inlet Guide Vane and Test Stator

	Inlet Guide Vane			Stator		
	Hub	Mean	Tip	Hub	Mean	Tip
Series Airfoil	63	63	63	65	65	65
Chord (in.)	3.00	3.00	3.00	6.546	6.546	6.546
Thickness Ratio	0.06	0.06	0.06	0.09	0.09	0.09
Camber (deg)*	-72.8	-72.8	-72.8	38.8	38.8	38.8
Inlet Metal Angle (deg)*	-18.2	-18.2	-18.2	48.9	48.9	48.9
Exit Metal Angle (deg)*	54.6	54.6	54.6	10.1	10.1	10.1
Aspect Ratio	1.306	1.306	1.306	0.554	0.554	0.554

\*Based on equivalent circular arc meanline.

Table III-1. Summary of Design Data For The  
Inlet Guide Vane and Test Stator (Continued)

	Inlet Guide Vane			Stator		
	Hub	Mean	Tip	Hub	Mean	Tip
Blade Chord Angle (deg)	35.7	35.7	35.7	29.5	29.5	29.5
Solidity	1.412	1.294	1.200	1.234	1.237	1.054
Inlet Absolute Mach Number	0.321	0.321	0.321	0.674	0.637	0.6085
Inlet Absolute Air Angle (deg)	0.0	0.0	0.0	51.6	50.4	49.3
Exit Absolute Air Angle (deg)	51.6	50.4	49.3	22.7	21.7	21.9
Diffusion Factor				0.552	0.528	0.504
Loss Coefficient	0.139	0.139	0.139	0.0439	0.0382	0.0348
Deviation (deg)	3.0	4.2	5.3	12.6	11.6	11.8

#### E. INSTRUMENTATION

Instrumentation was provided primarily for the measurement of midspan wake profile, chordwise pressure distribution, and stator air turning. Axial location of instrumentation stations are shown in figure III-3, and schematics showing the instrumentation in detail are presented in figures III-5 to III-9. The two instrumentation stations of primary concern are Stations 2 and 3A. Station 2 was located just ahead of the test stators and Station 3A was about 1/2 chord length downstream of the stators.

##### 1. Instrumentation for Rig Inlet Conditions

Weight flow was measured with an ASME standard thin plate orifice located in the inlet duct.

Six static pressure taps and six temperature probes were located in the plenum chamber for measurement of inlet total pressure and temperature. The circumferential and radial locations for this instrumentation are shown in figure III-6.

Three static pressure taps were located on both the inner and outer walls upstream of the inlet guide vanes (Station 0). From a rig calibration over a wide range of weight flows, a calibration between these static pressures and weight flow was derived and used to check subsequent weight flow measurements.

## 2. Stator Inlet; Station 2

Stator inlet conditions were measured at Station 2. A section view of the flow path at Station 2, showing the circumferential and radial location of the instrumentation, is presented in figure III-6. Inlet air angle measurements were obtained at three circumferential locations with 20-degree wedge traverse probes. Three Kiel probes were used for midspan total pressure measurement, and a wake probe was installed to measure inlet guide vane wake total pressure distribution. The wake probe was approximately aligned with the average guide vane exit air angle. Three static pressure taps were located on both the inner and outer wall.

A 20-degree wedge probe was added during the test program at midspan-midchannel approximately  $1/2$  chord length downstream of the inlet guide vane row (Station 1). This probe was added for measurement of guide vane exit angle at a position that was not influenced by the guide vane wakes. Figure III-6 shows the location of this probe in a section view of the flow path.

## 3. Stator Exit; Station 3A

Stator exit conditions were measured at Station 3A. A section view of the flow path at this station is shown in figure III-6.

Four 20-degree wedge traverse probes were used for stator exit angle measurement and four Kiel probes were used for midspan total pressure measurement. Two of the traverse probes were added during the test program. A wake probe was used for stator wake total pressure measurement. Eight static pressure taps were located around the outer wall to detect the presence of flow nonuniformity that might occur as a result of having unslotted stators in the lower half of the test section. Two static taps were located in the inner wall.

## 4. Stator Surface Pressure Taps

Three test stator vanes were instrumented with static pressure taps to provide a sufficient number of chordwise pressure measurements. The instrumented vanes are designated A, B, and C in figure III-5. The spanwise and

chordal locations of the pressure taps are shown in figure III-7. The location of taps in the slot region are shown in figures III-8 and III-9 for the forward and rear slots respectively. Figure III-10 illustrates the method of installation of the pressure taps.

Installation tolerances from vane to vane caused a small variation in stagger angle and consequently incidence angle. Because static pressure distribution is a function of incidence angle, stagger angles are tabulated below for the vanes with surface static pressure taps.

	Vane A $\gamma^\circ$ , deg	Vane B $\gamma^\circ$ , deg	Vane C $\gamma^\circ$ , deg
Unslotted and Forward Slot Configurations	29.0	29.75	30.0
Rear Slot Configurations	29.0	29.17	29.08

#### 5. Description of Probes

Details of the 20-degree wedge probe, wake probe, and Kiel probe are shown in figure III-11. The wedge probe contained side pressure pickups for air angle measurement, a total pressure pickup, and a total temperature pickup.

The wake probe contained 16 total pressure pickups formed by 0.042-in. (OD) hypo tubing and spaced as shown in the figure.

#### 6. Instrumentation Readout

All pressure and angle data were automatically recorded. Traverse probe data (total pressure and air angle) were recorded on magnetic tape at the rate of 60 samples (2.5 inches probe travel) per minute. Steady-state pressure measurements were obtained using Scannivalve multi-channel pressure transducer system that includes automatic data recording on IBM cards. Temperatures were indicated on a precision potentiometer, and manually recorded on IBM cards.

Plenum conditions and flow measuring orifice measurements were also recorded on manometer tubes in the test stand control room to permit setting the desired corrected flow conditions.

SECTION IV  
PROCEDURES

## A. TEST PROCEDURE

Two tests were conducted with the unslotted stators to provide data on which to base slot location and to provide data for a comparison between the unslotted and slotted stator performance. Subsequent tests involved alternative use of a forward and rear slot configuration. To simplify testing, it was desirable to slot only the stator vanes in the upper half of the annulus. Comparisons of circumferential distributions of wall static pressure for the unslotted tests and the initial slotted tests indicated that although there was a definite circumferential variation of static pressure, the pattern did not change appreciably when slotted vanes were installed in only the upper half of the annulus. Therefore, it was considered adequate to slot only half of the test vanes for this preliminary slot configuration investigation. A comparison of wall static pressures at the stator exit with and without slotted stators in the upper half of the test section is shown in figures IV-1 and IV-2.

The tests were conducted at an approximate stator inlet Mach number of 0.64 and a corresponding corrected weight flow of 81.5 lb/sec. Flow conditions were set by controlling the J75 slave engine exhaust flow through the ejector system. When steady-state flow conditions were established, fixed instrumentation pressure and temperature measurements were recorded. The traverse probes were then actuated and data recorded, followed by a second recording of fixed instrumentation pressures and temperatures.

Immediately before the end of each test, a solution of Blue Dykem metal marking dye and alcohol was injected through static pressure orifices onto the suction and pressure surfaces of the three instrumented stator vanes to provide visual inspection of the boundary layer flow characteristics.

## B. DATA REDUCTION PROCEDURE

### 1. Preliminary Data Reduction

An IBM computer program was used to convert magnetic-tape-recorded data and data recorded on IBM cards to engineering units. Traverse data (total pressure, total temperature, and air angle), obtained at approximately 0.04-inch increments across the span, were automatically plotted (as well as tabulated). The tabulated data were used to select midspan values of total pressure and air angle. The plotted data were inspected for general profile shape, as well as for inlet guide vane wake and secondary flow influences.

### 2. Parameter Calculation

The following parameters were calculated for the analysis of test data and the evaluation of slotted stator performance. Symbols are defined in Appendix A.

#### a. Static Pressure Coefficient

Stator vane surface static pressure measurements are presented in the form of pressure coefficients, defined as follows:

$$C_p = (p_l - \bar{P}_2) / \bar{q}_2$$

where:

$p_l$  = local vane surface pressure

$\bar{P}_2$  = arithmetic average of wall static pressures  
upstream of stator (Station 2)

$$\bar{q}_2 = \frac{\gamma}{2} \bar{P}_2 M_2^2$$

$$\gamma = 1.40$$

$$M_2 = f\left[\bar{P}_2 / \bar{P}_2\right]$$

and

$\bar{P}_2$  = area-average total pressure at Station 2  
(midspan)

## b. Total Pressure Loss Coefficient

Total pressure loss coefficient for the inlet guide vanes is defined as

$$\bar{\omega}_{0-2} = \frac{P_0 - \bar{P}_2}{q_0}$$

Guide vane inlet dynamic pressure,  $q_0$  was obtained as a function of inlet Mach number,  $M_0$ , which was determined from isentropic flow relationships using measured weight flow, plenum pressure and temperature, and the appropriate flow area.

Stator vane wake total pressure loss coefficient is defined as

$$\bar{\omega}_{2-3A} = \frac{\bar{P}_2 - \bar{P}_{3A}}{\bar{q}_2}$$

where  $\bar{P}_{3A}$  is the area-average total pressure at Station 3A (stator exit). Area-average total pressure at Stations 2 and 3A were obtained by manual integration of midspan wake total pressure distributions.

## c. Total Pressure Loss Parameter

Wake total pressure loss is also presented in terms of the loss parameter

$$\frac{\bar{\omega}_{2-3A} \cos \beta_{3A}}{2\sigma}$$

where:

$\beta_{3A}$  = stator exit air angle (Station 3A)

$\sigma$  = solidity, ratio of chord to spacing

## d. Diffusion Factor

Diffusion factor is defined as

$$D_F = 1 - \frac{V_{3A}}{V_2} + \frac{\Delta V_{\theta 2-3A}}{2\sigma V_2}$$



where:

$V_2$  = velocity at inlet to stator (Station 2)

$V_{3A}$  = velocity at exit of stator (Station 3A)

and

$\Delta V_{\theta \ 2-3A}$  = change in tangential velocity across the stator

e. Lift Coefficient

Lift coefficient is defined as

$$C_L = \frac{\int (p_p - p_s) dc}{\bar{q}_2 c}$$

where:

$p_p$  = static pressure on pressure surface

$p_s$  = static pressure on suction surface

$c$  = stator vane chord length

The pressure area term,  $(p_p - p_s)dc$ , was obtained by manual integration of the static pressure distributions. Each section of the slotted stator vanes was treated as a separate airfoil for the integration.

f. Stator Air Turning

Because of the influence of inlet guide vane wakes and secondary flows, the air angle measurements at midspan for different probes at a particular station varied by several degrees. The evaluation of the effect of slots on turning angle was therefore based on a study of individual probes selected on the basis of their proximity to wakes and the uniformity of indicated pressure and angle profiles in the midspan region.

## SECTION V RESULTS AND DISCUSSION

As stated previously, the objective of the annular cascade investigation of slotted stators was to provide guidelines for the design of slotted rotors and stators to be tested in a subsequent part of the overall program. In accordance with this objective, the cascade program was limited to the evaluation, based on mean radius measurements, of eleven slot geometry configurations and two slot locations. No attempt was made to resolve circumferential variations in wall static pressure and air angle; and end-wall boundary layer development through the 6.5-inch chord cascade was ignored.

The results of the annular cascade tests are presented in this section. Tabulations of total pressure, static pressure, and air angle data are included in Appendix B.

### A. UNSLOTTED STATOR VANE PERFORMANCE

#### 1. Inlet Guide Vanes

##### a. Exit Air Angle

Midspan air angle measurements behind the inlet guide vanes are summarized in table B-1. Air angle measurements obtained with each of the four wedge traverse probes are generally within  $\pm 1.0$  degree of the average angle for each probe. The air angles for different probes range from 45.3 to 53.7 degrees. This variation is attributed to slight differences in the location of each probe relative to adjacent guide vane wakes. On the basis of their overall average value, the guide vane exit air angles indicate that the stator may have been operating at approximately 2 degrees below design incidence, which would slightly unload the stator. Since the midspan air angle measurements encompassed the design value of 50.4 degrees, no attempt was made to improve the data by relocating probes to eliminate possible guide vane wake influence. Also, it was not considered necessary within the scope of the annular cascade program to restagger the guide vanes to increase the average exit angle to the design value. The guide vane design exit air angle was subsequently used in conjunction with stator exit air angles for evaluation of stator turning.

A typical measured spanwise distribution of air angle is compared with the design air angle distribution in figure V-1. The slope of the measured angle distribution matches that of the design distribution fairly well between about 25 and 75% span at a level approximately 2 degrees below the design values.

b. Total Pressure Loss

A typical guide vane midspan wake total pressure profile is shown in figure V-2. The profile is plotted as the ratio of local total pressure to inlet guide vane total pressure,  $P/P_0$ , vs channel distance in the plane of the probe. Vertical lines in the figure indicate the mid-channel projections of two adjacent channels. The wake probe was positioned so that it overlapped one complete channel width.

The size of the wake, with respect to the channel width, appears large because the measuring station is about 2 chord lengths downstream of the guide vane exit plane. The maximum local total pressure deficiency in the wake is very small (approximately 2%). The range of integrated values of total pressure ratio,  $\bar{P}_2/P_0$ , for all but two of the tests varied between 0.9953 and 0.9959. An average value of 0.9956 was used for all of the stator total pressure loss coefficient calculations. The guide vane loss coefficient based on this average total pressure ratio and an inlet Mach number of 0.324 is 0.0643, compared with the design loss coefficient value of 0.139.

2. Stators

a. Pressure Coefficient Distribution

The pressure coefficient ( $C_p$ ) curve for the unslotted stator (Configuration 1) is presented in figure V-3. Table B-2 lists the pressure coefficients for two different unslotted stator tests (Configurations 1 and 1A). Note in figure V-3 that the pressure coefficient curve flattens out at approximately 85% chord on the suction surface; this indicates apparent flow separation at this point. This is supported by the dye patterns shown in figure V-4, which indicate flow separation at approximately the same chordal location.

The suction surface portion of the curve in figure V-3 was drawn through the Vane A pressure coefficient data to permit consistent comparisons with the forward and rear slot configuration pressure coefficient distributions, as discussed in Section V, paragraph C.2.

## b. Total Pressure Loss

Midspan wake total pressure profiles for the two unslotted stator configuration tests are shown in figure V-5. Total pressure data are presented in table B-3. Values of loss coefficient,  $\bar{\omega}$ , based on integration of the wake profiles shown in figure V-5, are 0.071 and 0.068 for Configurations 1 and 1A, respectively.

Value of midspan loss parameter,  $\frac{\bar{\omega} \cos \beta}{2\sigma}$ , and D-factor for the unslotted stators were calculated for comparison with NACA stator loss data published in Reference 1\*. The calculated values are listed as follows:

Configuration	1	1A
Loss parameter	0.029	0.028
D-Factor	0.442	0.466

These results are compared in figure V-6 with NASA stator mean radius loss data for NACA 65-A<sub>10</sub> series airfoils and a loss correlation curve that represents root, mean, and tip section loss measurements for the NACA 65-A<sub>10</sub> series and double circular arc airfoils. Although the two annular cascade test points are not in good agreement with the correlation curve, they correlate fairly well with the NASA stator mean radius data.

## c. Air Turning Angle

Midspan stator exit air angles for the two unslotted stator tests are listed below:

Probe Circumferential Location, deg	24	228
	Stator Exit Air Angle, deg	
Configuration 1	23.8	21.4
Configuration 1A	23.7	21.4

The difference in the air angle values for the two different probes is attributed partly to their relative proximity to the adjacent stator vane wake. The probe at circumferential position 24 degrees is in close proximity to a vane pressure surface, whereas the probe at 228 degrees

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\*Reference 1: Aerodynamic Design of Axial Flow Compressors (Revised), NASA SP-36, 1965, pp 240 and 248.

is in close proximity to a vane suction surface. The angle measurements obtained with the first probe are therefore considered more reliable than those of the second probe. Based on the guide vane design exit angle of 50.4 degrees and the stator exit angles obtained with the 24-degree probe, the unslotted stator turning was 26.6 degrees compared with a design stator turning of 28.7 degrees.

## B. SLOT CONFIGURATION SELECTION

### 1. Slot Location

The following general criteria were established to determine the location of slots for the stator vanes:

1. The slot should be located upstream of the point of flow separation. If the slot flow exhausted into a separated region, it could not effectively turn the primary flow back toward the suction surface.
2. The slot should be located in a region where the pressure difference between the suction and pressure surfaces is sufficiently high to provide high slot flow velocity. High slot flow velocity was considered important in permitting sufficient energy addition to the suction surface boundary layer to provide unseparated flow essentially to the blade trailing edge.

The pressure coefficient distribution in figure V-3 indicates suction surface boundary layer separation at about 85% chord and a maximum pressure difference across the vane at approximately 12% chord (minimum pressure point location on suction surface). On the basis of the general criteria above, two slot locations between 12 and 85% chord were selected for evaluation. One slot was located at 75% chord, close to the separation point. The slot flow at this location was expected to eliminate flow separation by energizing the boundary layer region. The second slot was located at 55% chord. The function of the slot flow at this location was to energize the boundary layer prior to incipient separation.

## 2. Slot Geometry

Slot geometry variables of primary concern in this investigation were slot contraction ratio,  $Y_1/Y_2$ ; Coanda radius,  $R$ ; and pressure surface leading edge radius,  $r_1$ . Definitions of the geometry nomenclature and a summary of the slot dimensions for all of the configurations is presented in figure V-7. Although slot angle,  $\psi$ , and pressure surface radius,  $R_p$ , are considered to be significant variables, they were not systematically evaluated in this investigation.

The slot exit width,  $Y_2$ , was calculated on the basis of an arbitrary slot flow requirement equal to approximately 3% of the primary flow, using the theoretical pressure drop between the pressure and suction surfaces. The resulting slot configurations are shown in figures V-8 and V-9 for the forward and rear slots, respectively. Configurations not indicated in the sequence of configuration numbers between 2 and 18 refer to test geometries and Reynolds number conditions that were omitted from the planned test program as warranted on the basis of test results.

## C. SLOTTED STATOR VANE PERFORMANCE

### 1. Total Pressure Loss

Midspan total pressure data for the slotted stator configurations are summarized in table B-3. Wake profiles for a forward slot and a rear slot stator configuration are compared with an unslotted vane wake profile in figures V-10 and V-11, respectively. Midspan wedge and Kiel probe readings were translated to the wake probe channel and are superimposed on the wake profile for comparison. The actual circumferential locations of these probes are indicated in degrees.

Figure V-10 shows a comparison of an unslotted vane wake with the wake obtained with forward slot configuration 9. A significant reduction in wake size can be seen with a shift of the wake toward higher flow turning. The slight dip in pressure at channel distances of 0.6 and 2.0 inches are attributed to inlet guide vane wakes. A third guide vane wake appears at 3.6 inches where the stator vane wake is reduced because of the slot. In general, excellent agreement is seen between the translated probe pressures and the wake

probe pressures. The mismatch of the two Kiel probe readings in figure V-10 is attributed to their respective proximity to the steep part of the wake.

The wake profile for rear slot configuration 4 is compared with an unslotted vane wake profile in figure V-11. The rear slot wake is similar in size to that of the unslotted stator vane; however, a noticeable shift of the wake toward higher turning is apparent.

Midspan values of loss parameter and D-factor calculated for the slotted stator configurations are compared in figure V-12 with the NASA stator loss data (Reference 1). The annular cascade unslotted stator results are included for comparison. Loss coefficient, loss parameter, and D-factor for all of the annular cascade stator test configurations are summarized in table V-1.

Table V-1. Loss Coefficient, Loss Parameter, and D-Factor for Annular Cascade Stator Test Configurations

Configuration	D-Factor	$\bar{\omega}_{2-3A}$	$\frac{\bar{\omega}_{2-3A} \cos \beta_{3A}}{2\sigma}$
Unslotted			
1	0.442	0.071	0.029
1A	0.466	0.068	0.028
Slot at 55% Chord			
2	0.429	0.028	0.012
5	0.437	0.021	0.009
7	0.460	0.031	0.013
9	0.458	0.012	0.005
15	0.439	0.014	0.006
18	0.456	0.030	0.013
Slot at 75% Chord			
4	0.487	0.063	0.039
6	0.476	0.053	0.022
8	0.476	0.073	0.030
10	0.512	0.130	0.055
14	0.531	0.125	0.054

The 55% chord slot data in figure V-12 show a significant reduction in loss parameter level at the same general loading level as the unslotted stators. Also, a significant improvement in loss is indicated when compared to the NASA loss correlation curve and the NASA midspan stator loss data for 65-A<sub>10</sub> series airfoils. The losses and D-factor values for the 75% chord slot configurations are generally higher than those for the unslotted stator and NASA data. It was apparent from the wake profile in figure V-11 that the rear slot location had little effect on the size and shape of the stator wake, although the wake was shifted about 2 degrees toward higher turning. The higher D-factor level obtained with the rearward slot as compared to the unslotted configuration may be attributed to three-dimensional effects.

It is apparent from inspection of the D-factor values for all of the stator configurations that the slots did not affect turning sufficiently to produce a significant improvement in loading. It is considered that secondary flow build-up at the endwalls through the relatively long chord stator limited the loading level capability of both slotted and unslotted stators.

## 2. Lift Characteristics

Stator vane static pressure distributions were manually integrated according to the method discussed in Section IV, Paragraph B.2, to obtain lift coefficient. Static pressure data, in the form of pressure coefficients, are presented in table B-2. Pressure coefficient distributions for a typical forward slot configuration (9) and a typical rear slot configuration (4) are shown in figures V-13 and V-14, respectively. The pressure measurements obtained on stator vanes A, B, and C (figure III-5) are indicated by symbol. The difference in suction surface pressure coefficients for vane A and vane B in figure V-13 is believed to have resulted from the approximately 1.0-degree difference in stagger angle for these two vanes, as discussed in Section III, Paragraph E.4. The curves drawn through the data points in figure V-13 favor the vane A data because the installed chordal stagger of vane A most nearly matches the installed chordal stagger angles of vanes A and C for the rear slot configurations. The suction surface pressure coefficients for vanes A and C for the rear slot configuration in figure V-14 are seen to be in close agreement.



Although the pressure taps exposed in the slot regions of the three instrumented vanes were not all perpendicular to the surface, the pressures indicated by these taps were used as guides in defining the pressure distribution for the two separate airfoil sections. Dashed portions of the curves indicate where the distribution shape was estimated for integration purposes.

It is worth noting that the level of pressure on the suction surface at the forward slot exit is considerably lower ( $C_p = -1.0$ ) than the level of pressure at the rear slot exit ( $C_p = -0.3$ ). The relatively high velocity associated with the lower of the two pressures is a necessary part of the desired Coanda effect at the slot exit.

Lift coefficients for all of the stator configurations are shown in table V-2. In general, both the forward and rear slot configurations appear to have produced a slight increase in lift coefficient over that of the unslotted stator. The pressure data scatter negates a more detailed evaluation of lift coefficient.

Table V-2. Lift Coefficients for Stator Configurations

Configuration	Lift Coefficient
Unslotted	
1	0.710
1A	0.680
Forward Slot	
2	0.665
5	0.716
7	0.762
9	0.768
15	0.716
18	0.707
Rear Slot	
4	0.765
6	0.732
8	0.744
10	0.661
14	0.705

### 3. Air Turning Angle

Stator exit air angles are summarized in table B-5. Angle measurements obtained with probes at circumferential locations of 24, 65, 228, and 328 degrees are presented. The probe located at 228 degrees was in the lower half of the annulus behind unslotted stator vanes. Air angles obtained with the probe at 24 degrees were selected for comparison with the unslotted stator exit air angles because of the lack of sufficient comparative data at the other circumferential location behind the slotted vanes. A typical air angle distribution obtained with this probe is shown in figure V-15. The measured mean radius air angle and the design air angle distribution for the unslotted stator are included in the figure for comparison. The unslotted stator exit air angle (Section V, Paragraph A.1) was 23.8 degrees. The average stator exit air angle is 22.0 degrees for the forward slot configurations and 21.4 degrees for the rear slot configurations, resulting in an average increase in turning of about 2 degrees due to slots. This level of turning increase is generally consistent with the increase in lift coefficient that resulted from the slots. As shown in table B-5, no consistent variation in air turning was indicated for the slot configurations tested.

SECTION VI  
CONCLUDING REMARKS

Eleven slotted stator configurations and two slot chord locations were evaluated in an annular cascade of 6.5-inch chord stators to provide slot design guidelines for single stage rig blading. The relative performance characteristics of the different configurations were evaluated on the basis of loss coefficient, D-factor loading, lift coefficient, and turning calculated from mean-radius measurements. Although this investigation was limited in scope, it was extremely valuable in supplying the information needed to develop preliminary slot design criteria for application to the single stage rotor and stator blading that will be tested in a subsequent part of the overall program. A preferred slot location at approximately half the distance between the minimum pressure point and the separation point was determined. This slot location provided a greater reduction in wake loss than that obtained with a slot located in close proximity to the separation point. A preferred slot geometry was determined on the basis of minimum wake loss and maximum lift coefficient.

## A. EFFECT OF SLOT LOCATION ON PERFORMANCE

Although both slot locations produced an increase in exit air angle and lift coefficient, the slot at 55% chord produced a considerably greater reduction in wake loss than the slot at 75% chord. This result is attributed to two factors:

1. The available pressure drop across the stator vane (pressure-to-suction surface) at the 75% chord slot location was less than the pressure drop across the vane at the 55% chord slot location.
2. The suction surface boundary layer at 75% chord is thicker than at 55% chord.

The first of the above factors results in a relatively low slot flow velocity and thus reduces the Coanda effect. The thicker boundary layer requires a larger pressure gradient normal to the suction surface

to induce freestream flow toward the surface. These factors tend to support the result that the rear slot wake was shifted toward higher turning but not reduced in size (figure V-11).

#### B. EFFECT OF SLOT GEOMETRY ON PERFORMANCE

The effect of slot geometry on performance was less pronounced than the effect of slot location. The geometry parameter that produced the most significant reduction in wake size for a forward slot configuration was the rear section leading edge radius,  $r_1$ , (figure V-7). When this radius was increased from 0.028 to 0.056 in., the wake loss coefficient decreased from 0.031 to 0.012.

The Coanda radius was the most significant geometry parameter that was varied for the rear slot configuration. A slight increase in Coanda radius produced a slight decrease in wake loss (0.063 to 0.053). Subsequent increase in Coanda radius resulted in a large increase in wake loss coefficient (up to 0.130). This change in wake loss suggests the probability of an optimum Coanda radius. Insufficient data were obtained to evaluate the optimum Coanda radius for the forward slot location.

Additional two-dimensional or annular cascade investigation is needed to provide basic information on the mechanism of slot effectiveness. Such investigation should include systematic evaluation of slot location and geometry over a range of Mach numbers, incidence angles, and loading levels.

APPENDIX A  
LIST OF SYMBOLS

Symbol	Description	Units
$c$	Chord length	in.
$C_L$	Lift coefficient	
$C_p$	Static pressure coefficient	
$M$	Mach number	
$p$	Static pressure	psia
$P$	Total pressure	psia
$q$	Dynamic pressure, $1/2\rho v^2$	psia
$s$	Blade spacing	in.
$V$	Velocity	ft/sec
$\beta$	Air angle, measured from axial line	deg
$\gamma$	Ratio of specific heats	
$\gamma^\circ$	Blade chord angle	deg
$\sigma$	Solidity	c/s
$\bar{\omega}$	Total pressure loss coefficient	
Subscripts		
$l$	Local vane surface point	
$p$	Pressure surface	
$s$	Suction surface	
$\theta$	Tangential	
$0$	Guide vane inlet station	
$1$	Guide vane exit station	
$2$	Stator inlet station	
$3A$	Stator exit station	

APPENDIX B  
TABULATED DATA

Mean radius and wall static pressure data for all of the test configurations are presented in this appendix. The following tabulations are included:

- Table B-1. . . . . Guide Vane Exit Air Angle,  
midspan
- Table B-2. . . . . Vane Surface Static Pressure  
Coefficient
- Table B-3. . . . . Total Pressure, midspan
- Table B-4. . . . . Wall Static Pressure, Weight Flow,  
Mach Number, Dynamic Pressure
- Table B-5. . . . . Stator Exit Air Angle, midspan

Table B-1. Guide Vane Exit Air Angle

Configuration		Guide Vane Exit Air Angle (Midspan) $\beta$ , deg			
		Station			
		1	2		
Circumferential Location, deg		18	143	243	323
Unslotted					
1			46.9	51.8	48.0
1A			47.4	51.8	47.9
Forward Slot					
2			42.5	52.3	47.4
5			45.4	51.5	48.5
7			45.4	51.4	50.0
9			45.9	51.7	47.5
15		48.3	45.8	53.7	47.4
18		50.1		49.4	47.6
Rear Slot					
4			46.0	51.3	47.3
6			45.6	50.6	48.5
8			45.8	51.0	48.9
10		48.2	46.3	51.8	47.1
14		46.4	45.3	51.4	46.8

Table B-2. Static Pressure Coefficients

	Percent Chord	Percent Span	Unslotted Stator			Forward Slot Configurations					Rear Slot Configurations				
			1	LA	2	5	7	9	15	18	4	6	8	10	14
Vane A	5	67.96	-0.6899	-0.6498	-0.5809	-0.7059	-0.8334	-0.9033	-0.6326	-0.8659	--	-0.6000	-0.7279	-0.5362	-0.5797
	10	50.00	-0.7562	-0.7046	-0.6625	-0.6866	-0.7831	-0.8447	-0.6212	-0.8114	-0.8157	-0.7881	-0.9038	-0.6743	-0.7623
	15	32.04	-0.7180	-0.7004	--	--	--	--	--	--	--	--	--	0.2171	0.2316
	20	58.98	-0.6879	-0.6159	-0.5257	-0.5967	-0.5350	-0.6072	-0.5101	--	--	-0.6975	-0.8702	-0.6502	-0.6845
	25	41.02	-0.6556	-0.6184	-0.4957	-0.5649	--	-0.3418	--	--	--	-0.5400	-0.6721	-0.5006	-0.4699
	30	67.96	--	--	-0.3934	-0.5541	-0.5534	-0.5112	-0.3345	-0.4927	--	-0.5409	-0.6423	-0.4263	-0.4256
	35	50.00	--	-0.4781	-0.3207	-0.4502	--	-0.1309	-0.0212	--	-0.4881	--	-0.5542	-0.4022	-0.3797
	40	32.04	--	--	-0.2000	-0.3033	--	-0.0016	--	--	--	-0.3025	-0.4558	-0.2743	-0.2165
	45	58.98	-0.3471	-0.3657	0.1049	0.3095	0.4384	0.5621	0.5991	--	--	-0.2681	-0.4173	-0.2327	-0.2158
	50	41.02	--	--	-0.2553	-0.2708	-0.4616	-0.4273	-0.0449	-0.1798	-0.1529	-0.1434	-0.2663	-0.0667	-0.0801
Suction Surface	55	67.96	-0.1392	-0.1537	-0.0849	-0.0826	-1.0425	-1.0115	-0.5462	-0.7543	-0.0378	0.0	-0.1173	-0.0371	-0.0718
	60	50.00	-0.1062	-0.0025	-0.2059	--	-0.3394	-0.3155	-0.1370	-0.2991	-0.1202	-0.0478	-0.1904	-0.0429	-0.0655
	65	32.04	--	--	-0.0148	--	-0.1783	-0.0323	-0.1259	--	-0.0189	-0.0022	-0.0843	-0.0241	0.0079
	70	58.98	--	--	-0.0079	-0.0692	-0.1244	-0.1023	0.0358	-0.0530	--	--	--	--	--
	75	41.02	0.1108	0.0774	0.1411	0.0502	-0.0100	-0.0072	0.1076	0.0470	--	-0.3084	-0.4410	-0.1737	-0.0937
	80	67.96	--	--	0.1168	0.0443	0.0381	0.0572	0.1092	0.0760	-0.0378	0.0	-0.1173	-0.0371	-0.0718
	85	50.00	0.2271	0.2102	0.1368	0.1249	0.1356	0.1220	0.2006	0.1385	0.0622	0.0109	-0.5154	0.0486	0.0285
	90	32.04	--	--	0.1740	0.1393	0.1631	0.1743	0.2025	0.1811	0.1522	0.1631	-0.6170	0.1311	--
	95	67.96	-0.5310	-0.5587	-0.4872	-0.6026	-0.5972	-0.5095	-0.4991	-0.4653	-0.6135	-0.6375	-0.5596	-0.3737	--
	Vane C	2.5	67.96	--	--	-0.6582	-0.7344	-0.6569	-0.5803	--	--	-0.7869	-0.7472	-0.6215	-0.6394
7.5		50.00	-0.6984	-0.6413	-0.6079	--	-0.6894	-0.6102	-0.6851	-0.6391	-0.7667	-0.7547	-0.6359	-0.6286	--
12.5		32.04	-0.7000	-0.6406	-0.6036	-0.7266	-0.7247	-0.6474	-0.7500	-0.6685	-0.7667	-0.7503	-0.8833	-0.6568	--
17.5		58.96	-0.6327	-0.5629	-0.4924	-0.6039	-0.5778	-0.5105	-0.6028	-0.5224	-0.6849	-0.6138	-0.8000	-0.5781	--
22.5		41.02	-0.5601	-0.5071	-0.3773	-0.5170	-0.4953	-0.4313	-0.5706	-0.4760	--	-0.5678	-0.7141	-0.5521	--
27.5		67.96	--	--	-0.2924	-0.4370	-0.3991	--	-0.4456	-0.3915	--	-0.4928	-0.6439	-0.4921	-0.4785
32.5		50.00	-0.3993	-0.3675	-0.2069	--	-0.3372	-0.2720	-0.3978	-0.3129	--	-0.3988	-0.5391	-0.4130	--
37.5		32.04	-0.3477	-0.3216	-0.1046	-0.1977	-0.1772	--	-0.2576	-0.1612	-0.3333	-0.3131	-0.4647	-0.3187	--
42.5		58.98	-0.1386	-0.1265	0.0595	-0.0679	-0.0525	--	-0.1307	-0.0666	-0.2750	-0.2409	-1.0490	-0.2879	--
47.5		41.02	--	--	0.1654	--	0.2734	0.3632	0.5117	0.2666	-0.1628	-0.1531	-0.2833	-0.1702	-0.1196
Vane B	52.5	67.96	--	--	-0.7862	-1.0570	-0.9459	-0.8523	-0.8003	-0.4192	-0.0955	-0.0778	-0.2042	-0.1314	--
	57.5	50.00	-0.0245	-0.0018	-0.0069	-0.0839	-0.2819	-0.1816	-0.2259	-0.4057	0.0407	0.0256	-0.0718	-0.1232	-0.0725
	62.5	32.04	0.1016	0.0933	-0.0158	-0.0839	-0.0241	0.0188	-0.0266	-0.0356	--	--	--	--	-0.2918
	67.5	58.98	0.1399	0.1438	0.1513	-0.0285	0.0309	0.0645	0.0301	0.0644	--	--	--	--	-0.2003
	72.5	41.02	0.1908	0.1731	0.1526	0.1026	0.1575	0.1924	0.1263	0.1830	0.0407	0.0256	-0.0718	-0.1232	-0.0725
	77.5	67.96	0.2082	0.2049	0.1993	0.1170	0.1472	0.1868	0.1256	0.1729	--	0.1316	-0.0183	0.0810	0.0421
	82.5	50.00	0.2271	0.2053	0.1809	--	0.1528	0.1911	0.1497	0.1767	--	0.1497	0.2206	0.1784	0.1715
	87.5	32.04	0.2239	0.2230	--	--	0.4031	0.2516	0.2130	0.2035	0.7913	0.2206	0.1192	0.1784	0.1715
	92.5	67.96	--	--	--	--	--	--	--	--	1.0561	1.0184	0.9670	1.0410	--
	Pressure Surface	0	32.04	1.0696	1.0378	1.0378	0.9928	1.0084	1.0520	1.0411	0.0789	--	0.2586	0.1234	0.2785
5		50.00	0.3369	0.3287	0.1724	0.5020	1.1847	1.1714	1.1446	0.2785	0.2516	0.2156	0.1234	0.2317	0.0789
10		67.96	0.3693	0.3498	0.2398	0.2195	0.1428	0.2398	0.2348	0.1631	0.2947	0.2981	0.1990	0.2854	0.1631
15		41.02	0.3498	0.3393	0.1694	0.1868	0.1188	0.2099	0.2003	0.1473	0.3140	0.1990	0.2237	0.2746	0.1473
20		58.98	0.3716	0.3604	0.2563	0.2003	0.1881	0.2263	0.2652	--	0.3301	0.3166	0.2138	0.2746	0.1473
25		32.04	0.3578	0.3318	0.2000	0.1538	--	--	--	--	0.3109	0.2697	0.1974	0.3105	--
30		50.00	0.3794	0.3622	0.1931	--	--	--	--	--	0.3407	0.3269	0.2378	0.3375	--
35		67.96	0.3967	0.3693	--	--	0.3456	--	--	0.4652	0.3603	0.3319	0.2577	0.3381	0.3609
40		41.02	0.3977	0.3671	0.3613	0.3613	0.4184	0.4849	0.4788	0.3959	0.3429	0.3159	0.2433	0.3241	0.3959
45		58.98	0.4065	0.3717	0.2510	0.1997	0.5059	0.5447	0.5937	0.5120	0.3465	0.3356	0.2510	0.3295	0.5120



Table B-3. Total Pressure, Midspan (psia)

Configuration	1	1A	2	5	7	9	15	18	4	6	8	10	14
Plenum Pressure, P <sub>0</sub>	14.391	14.413	14.376	14.416	14.368	14.407	14.424	14.466	14.449	14.466	14.393	14.380	14.430
Probe													
Circumferential Location, deg													
Wake Probe													
1 (Tube No.)													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
Wedge Probe													
143.0	13.942	14.251	14.058	14.055	14.252	14.019	13.918	14.131	14.082	14.059	13.942	13.877	13.967
243.5	14.129	13.933	14.075	14.069	14.123	14.077	14.062	14.443	14.082	14.132	14.028	13.949	14.040
328.5	14.172	14.207	14.331	14.329	14.238	14.365	14.206	14.169	14.285	14.417	14.215	14.079	14.126
63.5	14.072	14.293	14.374	14.416	14.180	14.365	14.408	14.414	14.530	14.464	14.388	14.381	14.429
219.0			14.158	14.142					14.082	14.204	14.114	14.365	14.415
293.5													

Station 2A (Stator Exit)

Wake Probe													
358.8													
1 (Tube No.)													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
Wedge Probe													
24.4													
65.8													
228.5													
328.8													
13.8													
121.3													
280.5													
310.5													

Table B-4. Wall Static Pressure, Weight Flow, Mach No., and Dynamic Pressure

Configuration	1	1A	2	5	7	9	15	18	4	6	8	10	14
Plenum Pressure	14.391	14.413	14.376	14.416	14.368	14.407	14.424	14.466	14.449	14.466	14.393	14.380	14.430
Tap Position, deg					Station 2 (Stator Inlet)								
193.5 ID	10.933	11.229	10.986	11.131	10.954	11.115	10.823	11.094	11.098	11.119	10.914	10.912	10.975
83.0 ID	10.859	11.131	10.837	11.035	10.565	10.707	10.262	10.620	10.503	10.371	10.320	10.357	10.356
3.0 ID	10.340	10.733	10.041	10.213	9.890	10.231	10.166	9.955	9.983	9.884	9.708	10.208	10.284
263.0 ID	11.381	11.634	11.440	11.644	11.452	11.586	11.659	11.508	11.531	11.562	11.424	11.455	11.487
133.0 ID	11.104	11.381	11.251	11.195	11.030	11.126	10.790	10.806	11.247	11.267	10.986	10.827	10.897
32.5 ID	11.471	11.789	11.463	11.361	11.249	11.479	11.560	11.433	11.482	11.495	8.805*	11.375	11.463
					Station 3A (Stator Exit)								
331.5 OD	12.150	12.323	12.066	12.051	11.982	12.187	12.061	12.035	12.088	12.114	8.808*	11.831	11.972
238.8 OD	12.018	12.319	12.028	12.177	11.990	12.182	12.070	11.923	12.103	12.213	8.807*	11.954	12.043
169.5 OD	12.006	12.275	12.056	12.080	12.963	12.183	12.000	11.894	12.163	12.175	8.807*	11.957	12.027
115.5 OD	12.054	12.369	12.154	12.140	12.036	12.246	11.992	12.003	12.263	12.223	12.004	12.004	12.151
61.5 OD	12.111	12.347	12.164	12.204	12.073	12.232	12.973	12.015	12.231	12.194	12.060	11.922	12.134
43.5 OD	12.257	12.505	12.401	12.348	12.266	12.448	12.126	12.331	12.391	12.343	12.173	12.109	12.252
12.359 ID	12.054	12.600	12.437	12.427	12.276	12.474	12.312	12.311	12.506	12.471	12.292	12.165	12.265
295.5 ID	11.989	12.247	11.989	11.963	11.833	12.068	12.013	11.955	12.034	12.074	11.807	11.781	11.932
193.9 ID	12.151	12.395	12.209	12.364	12.201	12.400	12.125	12.225	12.394	12.373	12.174	12.159	12.268
48.7 ID	12.230	12.462	12.281	12.342	12.246	12.397	12.054	12.195	12.349	12.290	12.146	12.085	12.239
Ω, 1b/sec	82.53	80.05	81.44	81.06	81.43	80.17	81.49	81.43	81.34	81.46	81.47	81.52	81.49
M <sub>0</sub>	0.321	0.309	0.316	0.314	0.316	0.310	0.316	0.316	0.316	0.316	0.316	0.316	0.316
M <sub>2</sub>	0.630	0.598	0.630	0.622	0.647	0.629	0.648	0.646	0.640	0.636	0.638	0.647	0.645
q <sub>0</sub> , psia	0.984	0.920	0.959	0.947	0.959	0.925	0.959	0.959	0.959	0.959	0.959	0.959	0.959
q <sub>2</sub> , psia	3.06	2.83	3.04	3.05	3.20	3.04	3.16	3.17	3.12	3.20	3.12	3.15	3.16

Pressure units are psia.

\* Not used to obtain average values.

Table B-5. Stator Exit Air Angle, Midspan

Configuration	Circumferential Location, deg	Stator Exit Air Angle, Midspan, deg			
		24	65	228	328
Unslotted					
1		23.8		21.4	
1A		23.7		21.4	
Average		23.7			
Forward Slot					
2		23.5		21.9	
5		21.9		18.5	22.9
7		21.9		18.3	22.3
9		21.7		18.2	23.2
15		24.3*	21.9	20.0	21.9
18		21.2	22.4	21.2	22.6
Average		22.0			
Rear Slot					
4		21.6		21.3	22.2
6		21.7			22.6
8		23.9		18.9	22.8
10		21.4	22.8	19.3	24.4
14		18.6	21.9	19.0	19.9
Average		21.4			

\*Not used to compute average.

APPENDIX C  
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APPENDIX D  
ILLUSTRATIONS

Figures in the following pages are presented as cited in this report.

FD 10891A

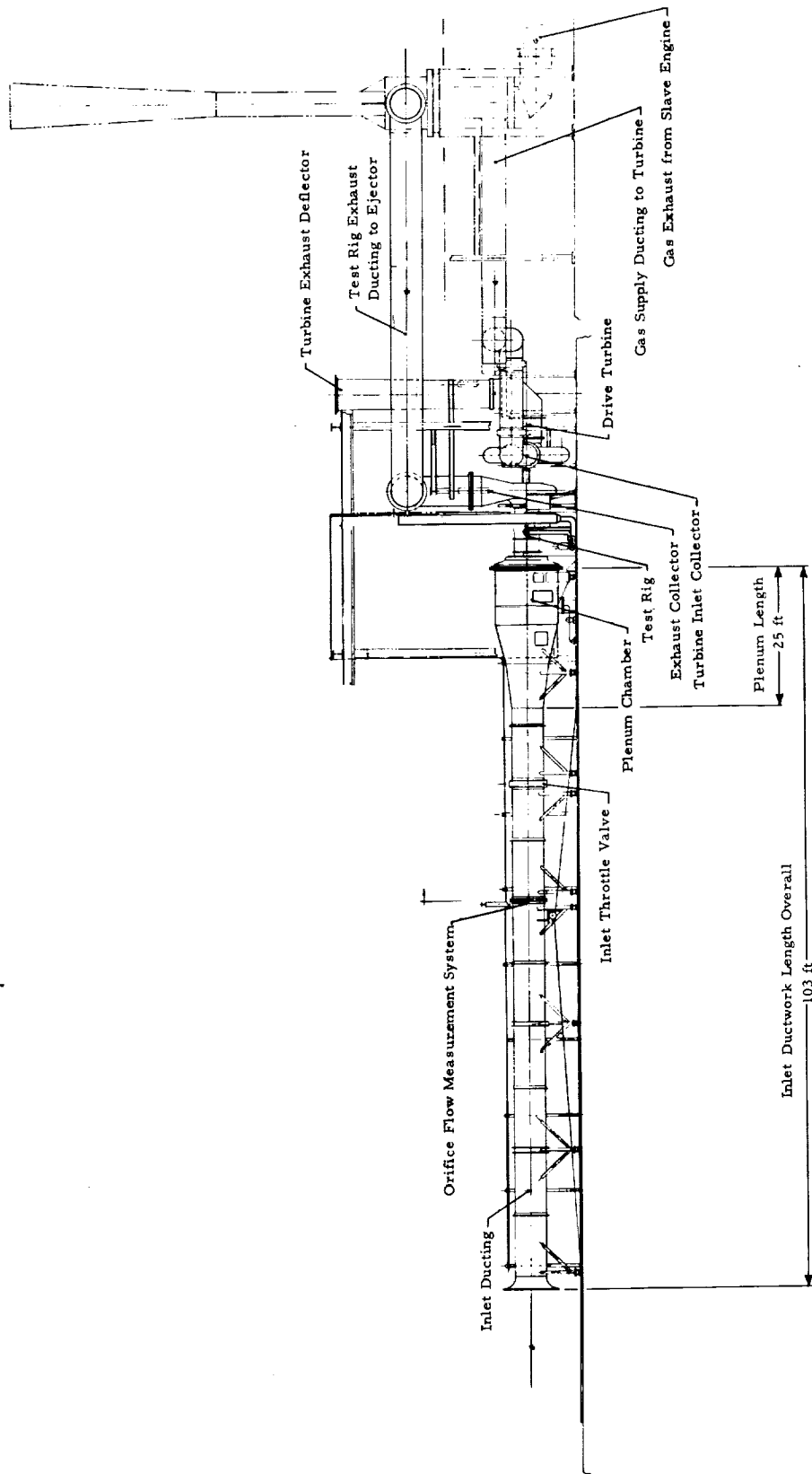


Figure III-1. Schematic of the Compressor Research Facility

FE 51208

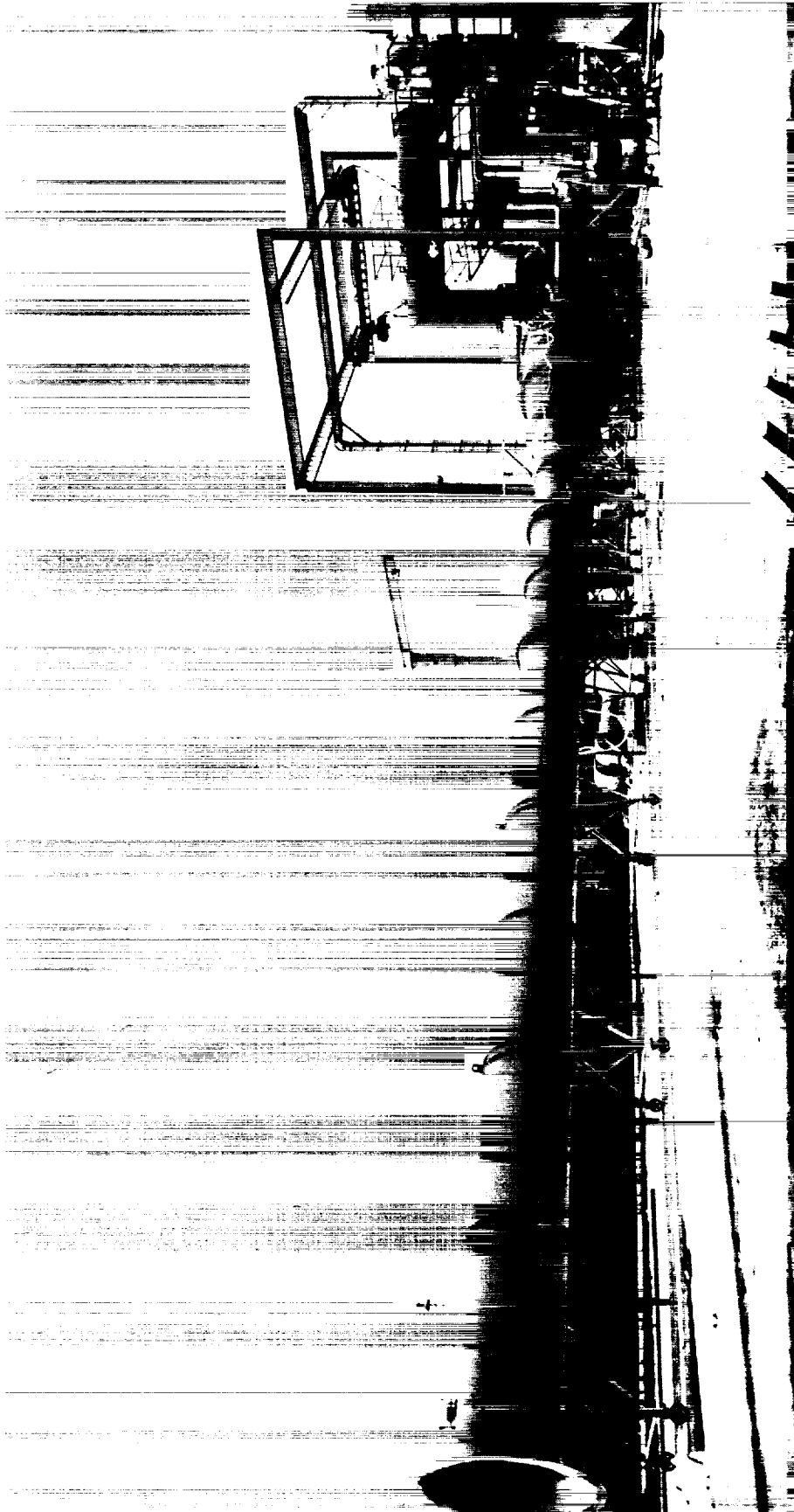
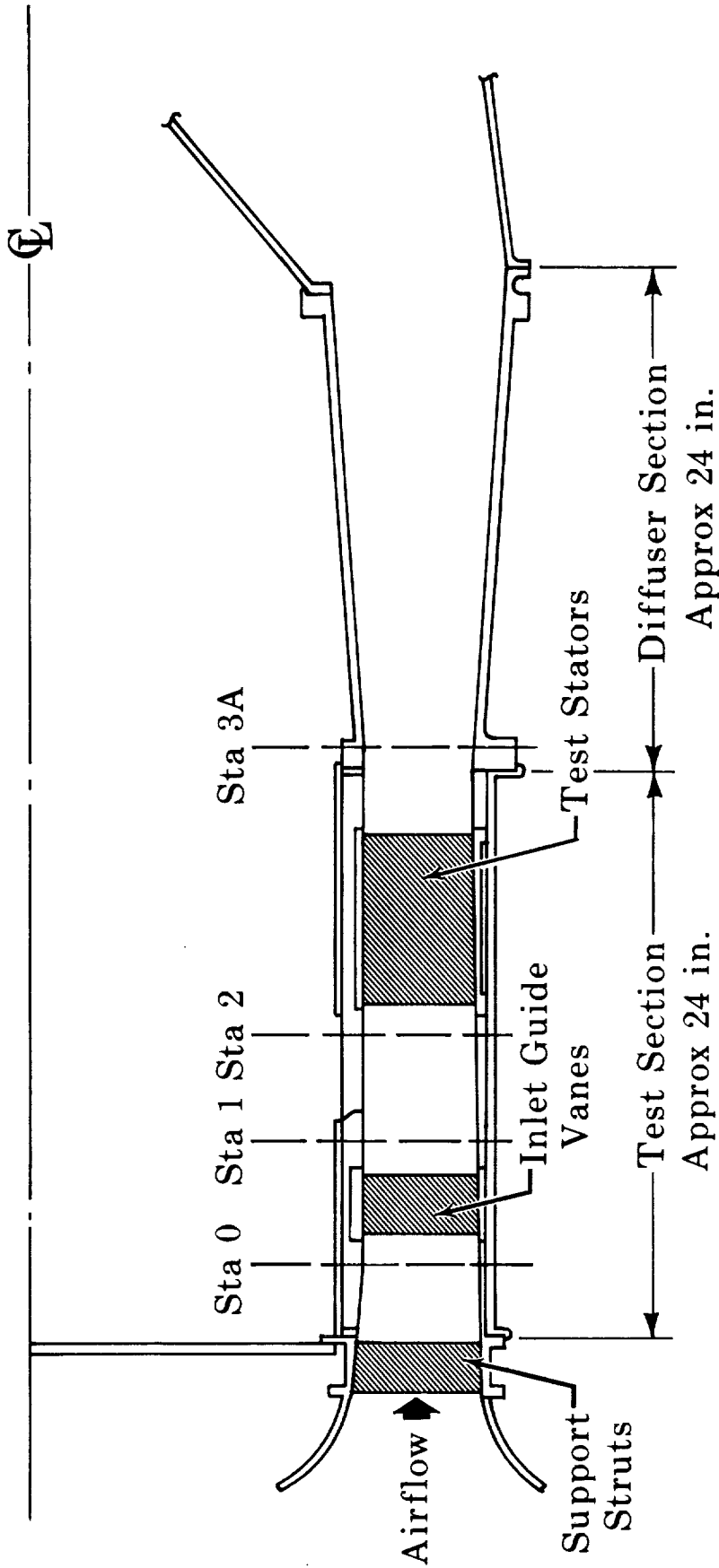


Figure III-2. Compressor Research Facility

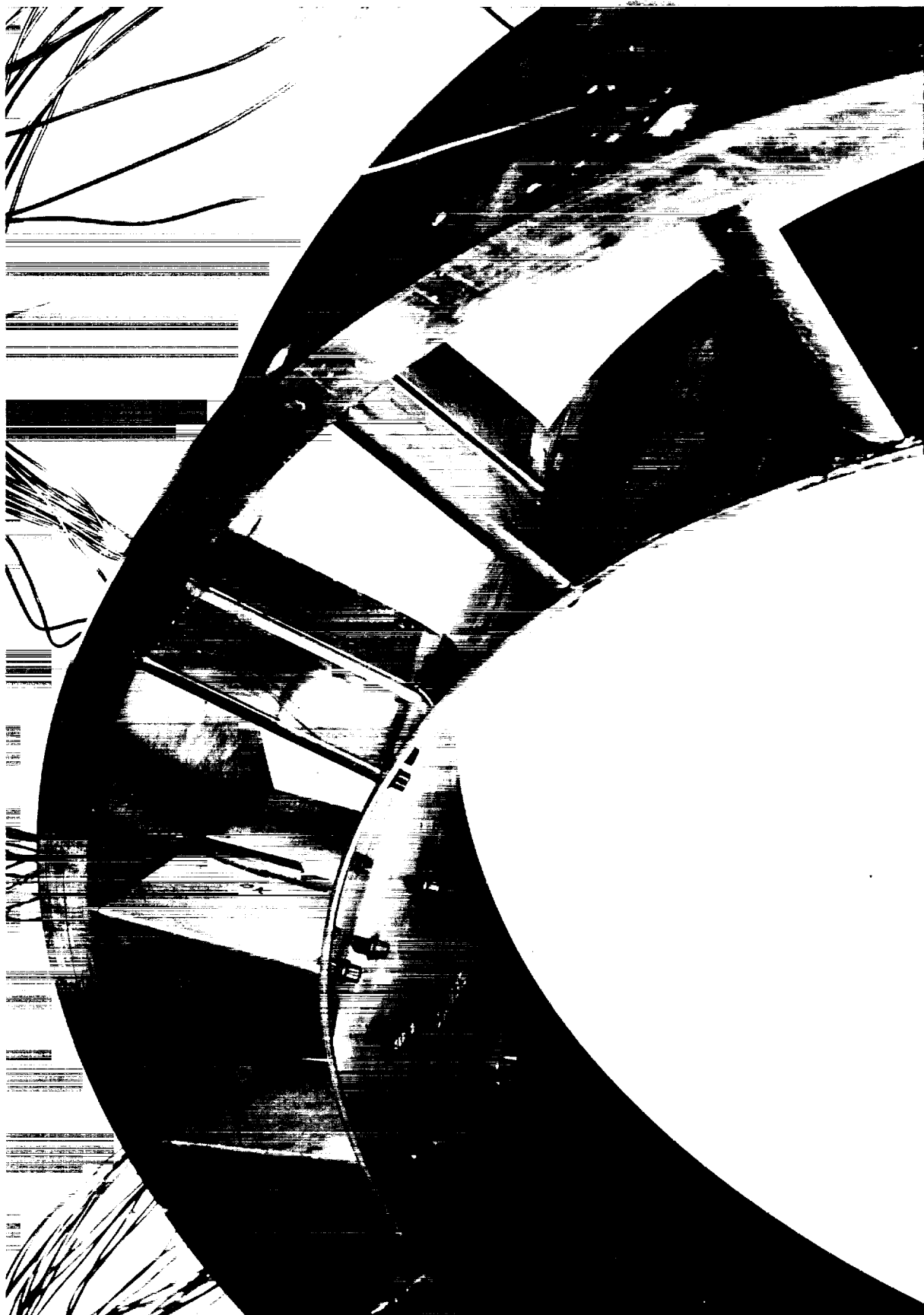


Measuring Station Diameters - in.

Station	ID	OD
0	32.38	41.12
1	32.85	40.57
2	32.85	40.23
3A	32.85	39.99

Figure III-3.. Schematic of Annular Cascade Rig

FD 14997B



FE 53351

Figure III-4. Stator Vane Assembly



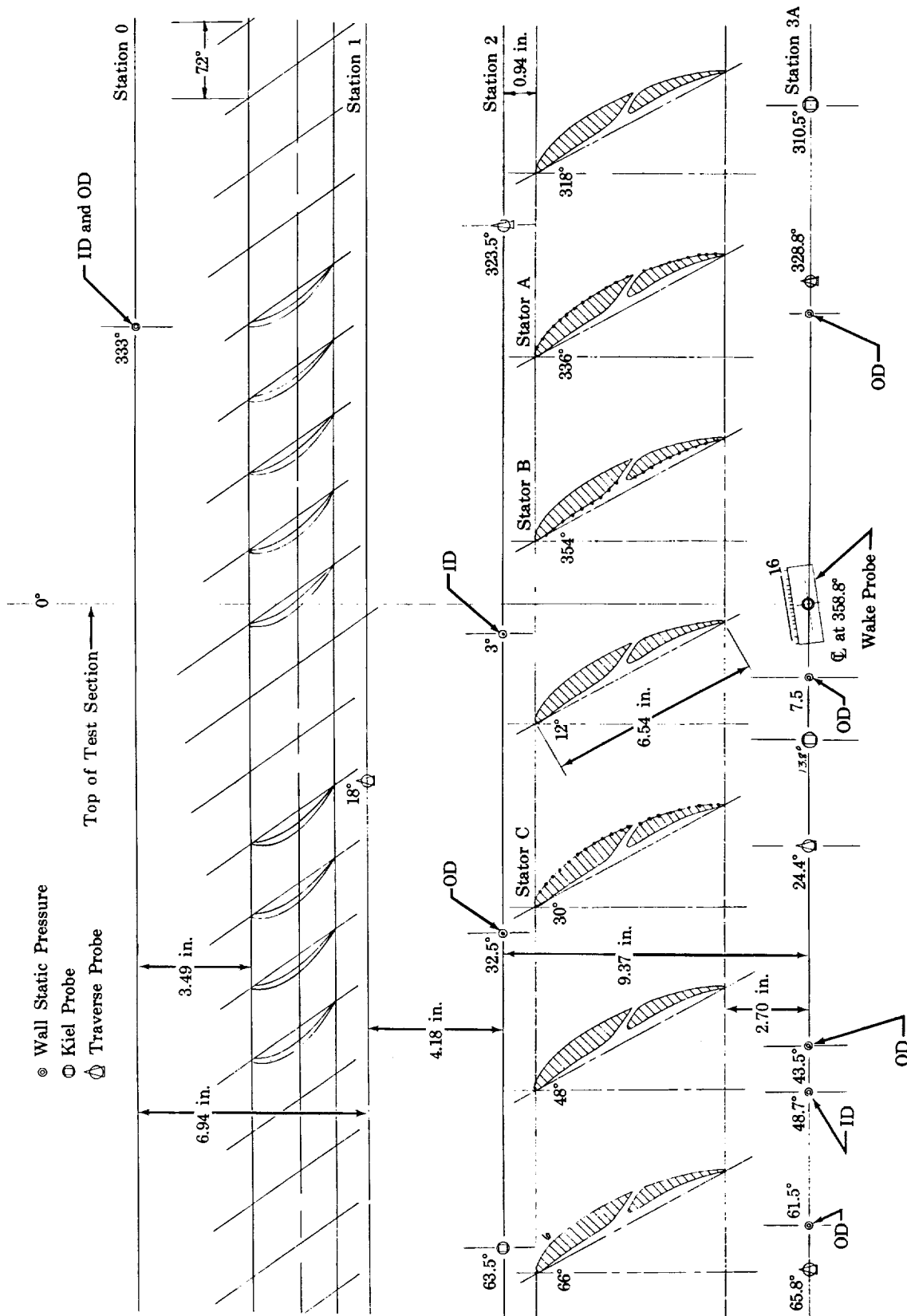


Figure III-5. Test Section Instrumentation Layout

FD 14973B

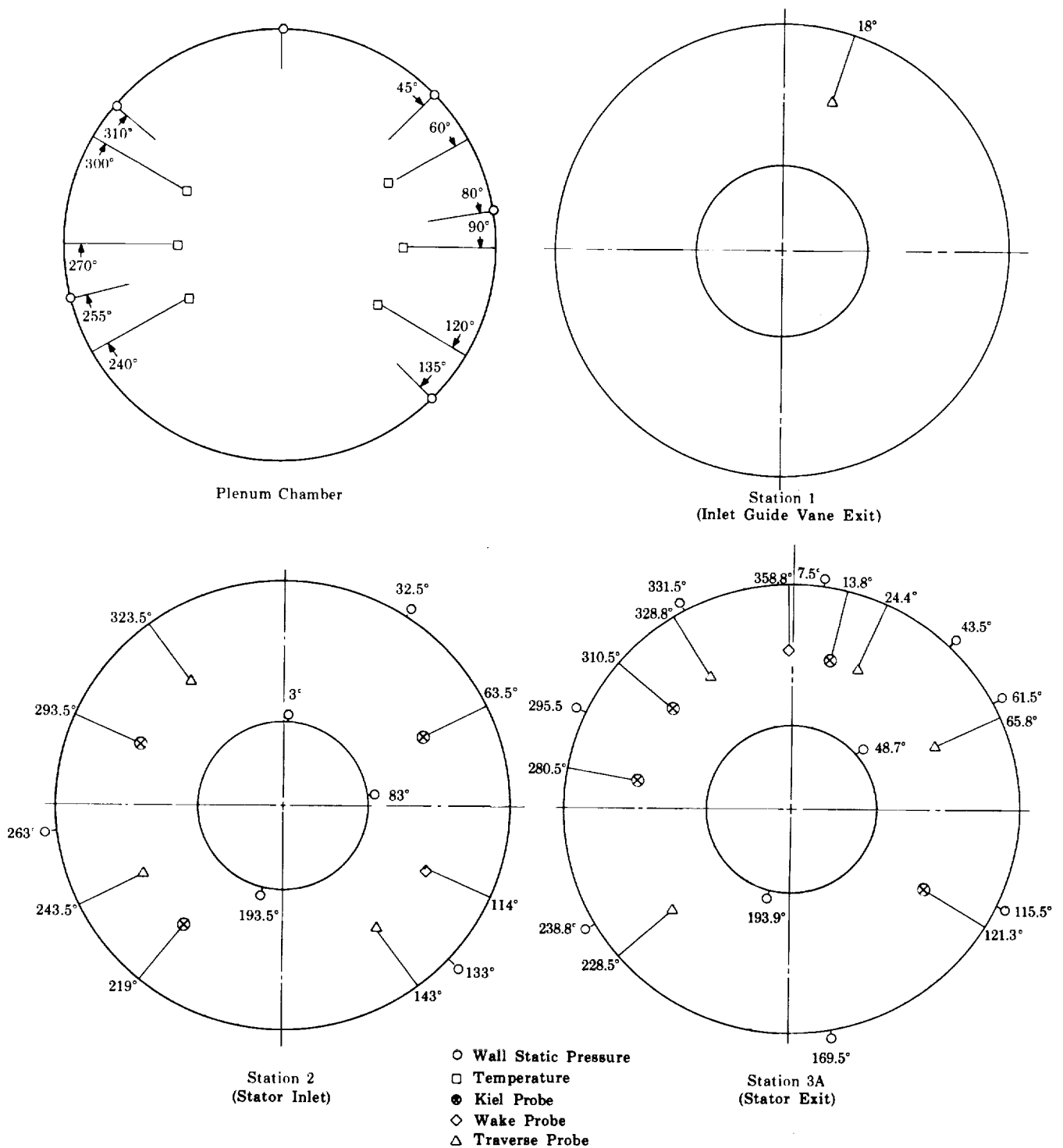
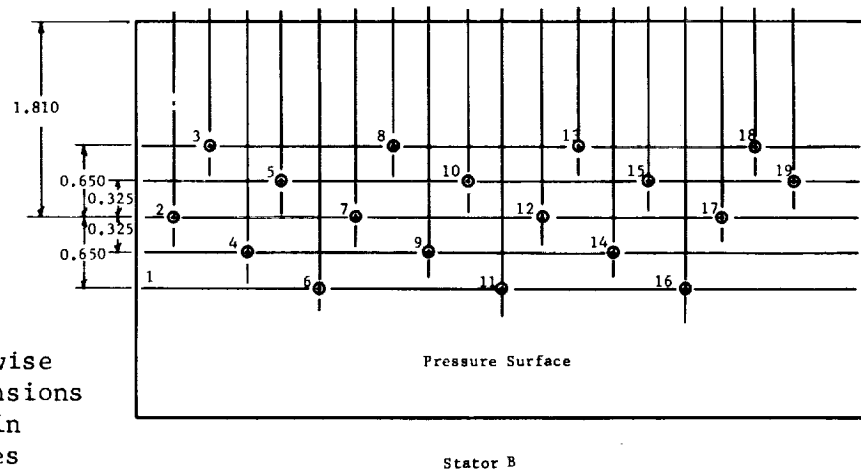
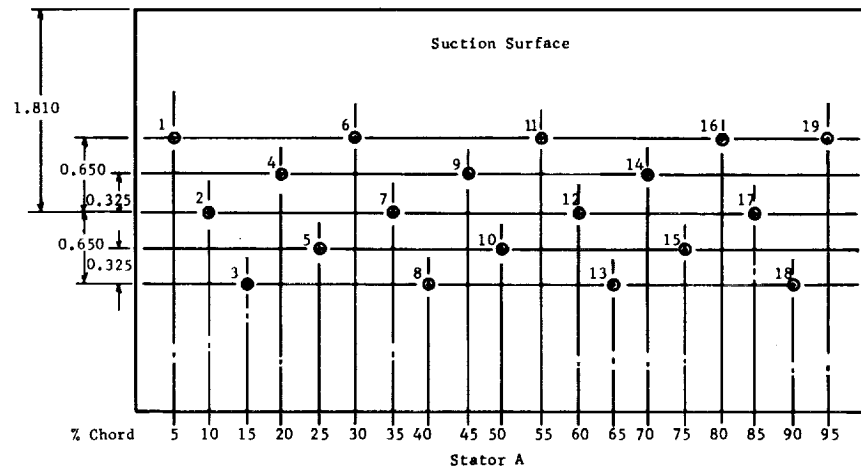


Figure III-6. Instrumentation, Plenum Chamber and Stations 1, 2, and 3A (View Looking Downstream)

FD 14975A



Note: Spanwise dimensions are in inches

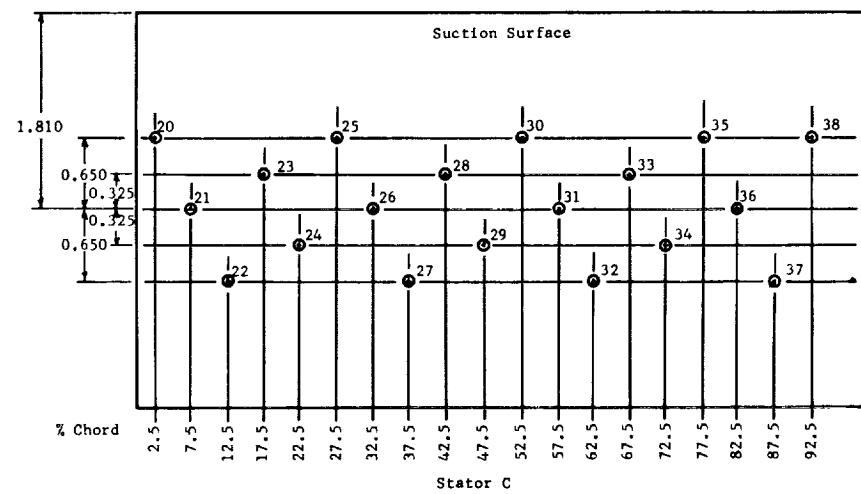


Figure III-7. Stator Surface Pressure Tap Locations

FD 14998

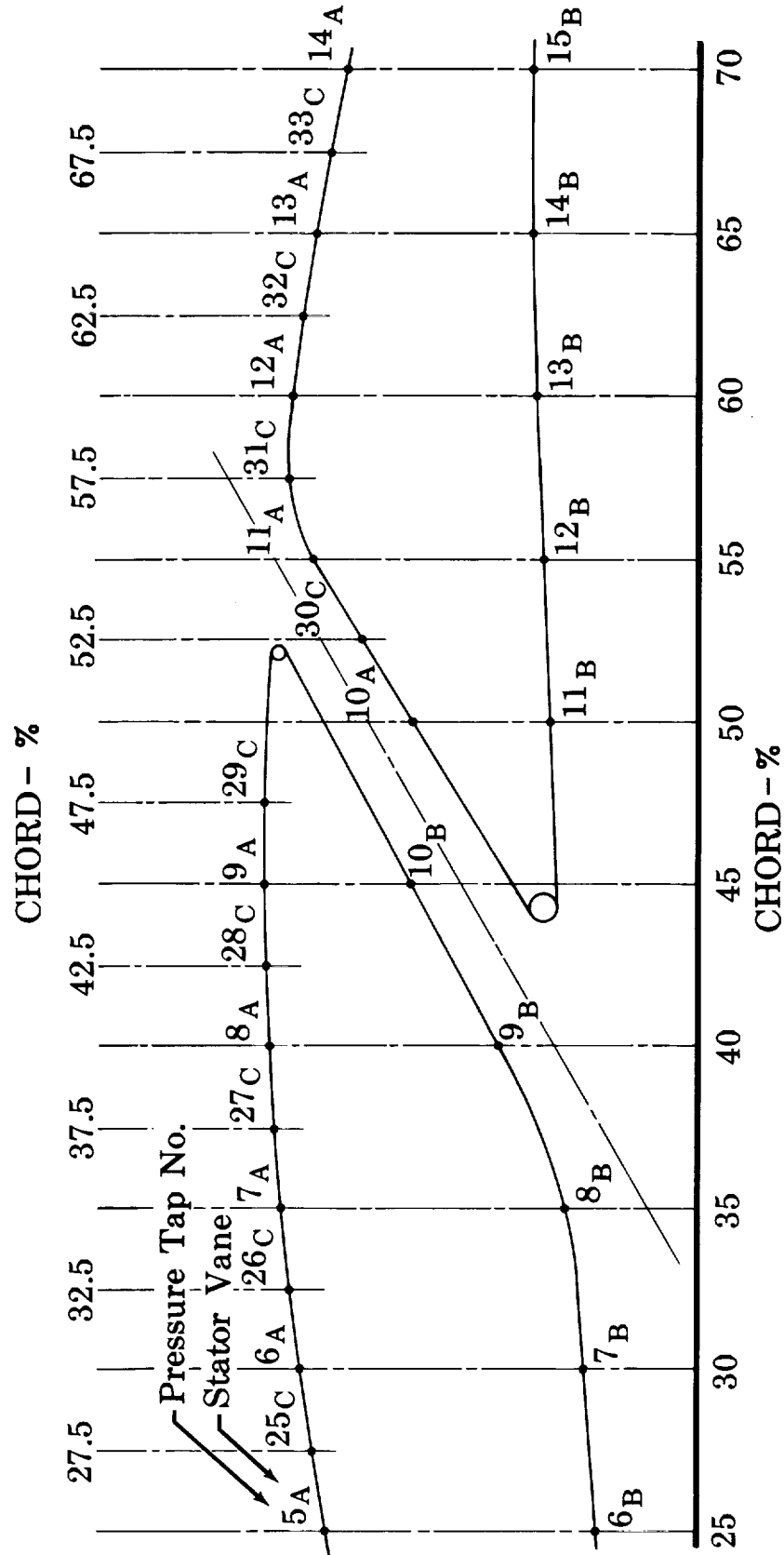


Figure III-8. Static Pressure Tap Locations Near Forward Slot

FD 14976A

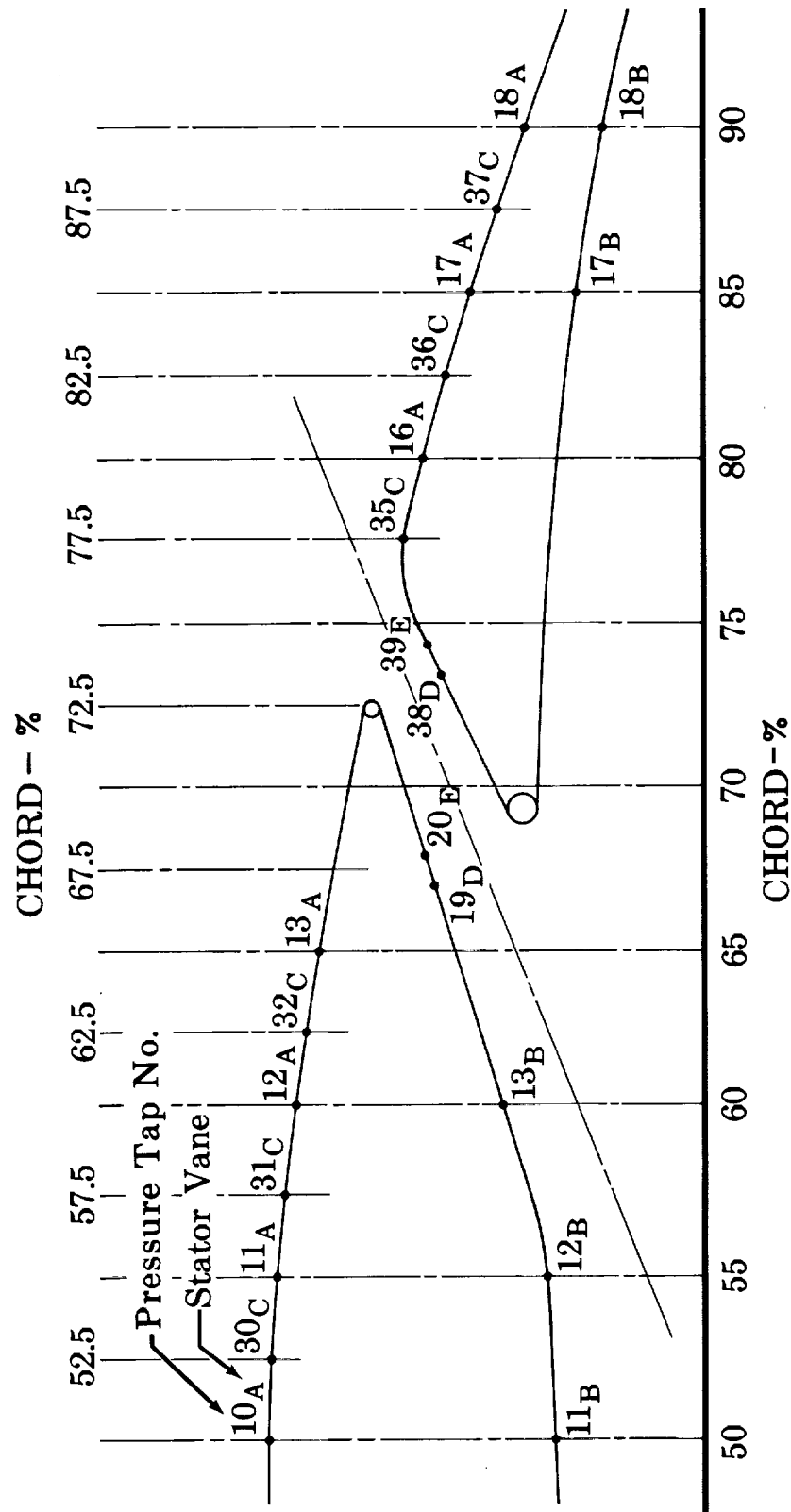


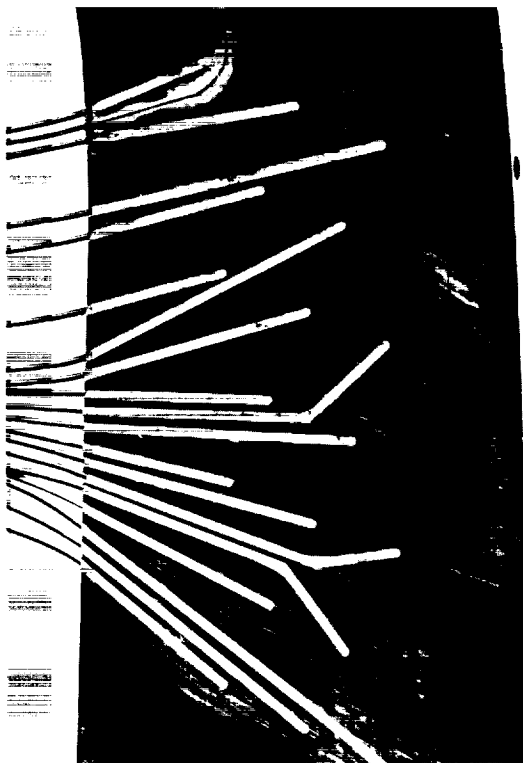
Figure III-9. Static Pressure Tap Locations Near Rear Slot

FD 14974A

FD 15005



Pressure Taps Drilled into  
Sealed Grooves from Opposite Surface



Hypo Tubing Sealed into  
Grooves with Epoxy

Figure III-10. Static Pressure Tap Installation

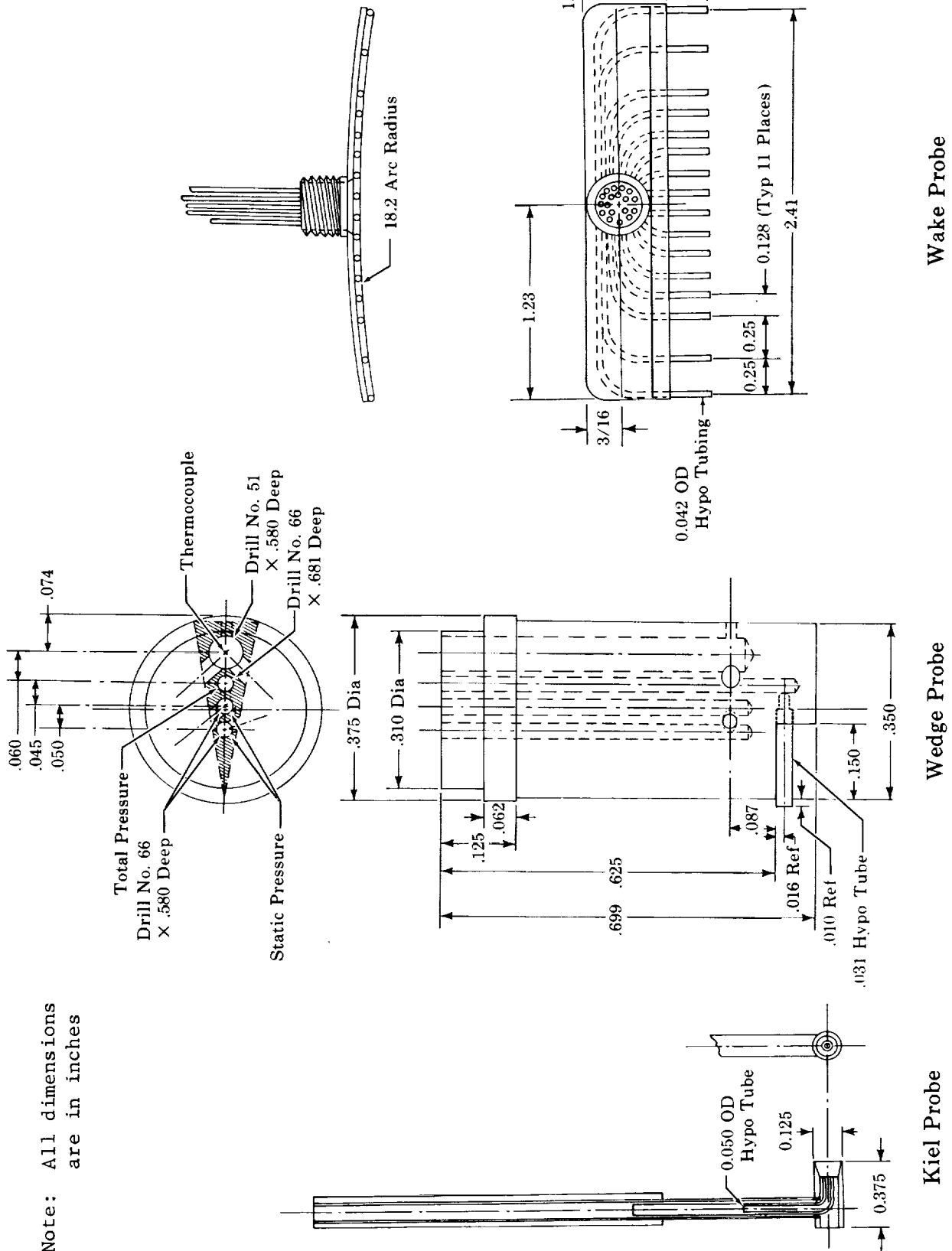


Figure III-11. Total Pressure Probes

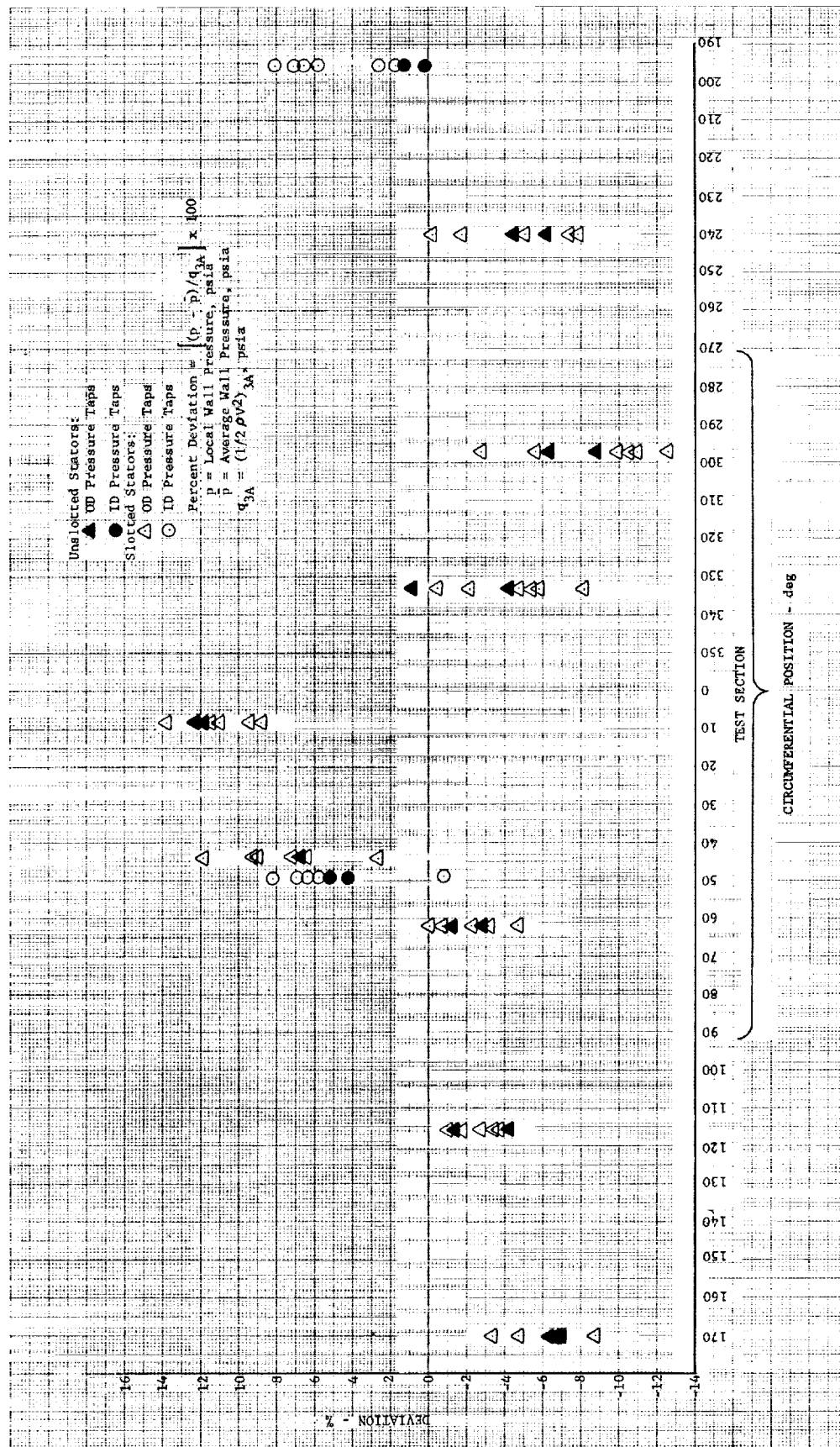


Figure IV-1. Circumferential Static Pressure Deviation at Station 3A (Forward Slot Configurations) DF 45542



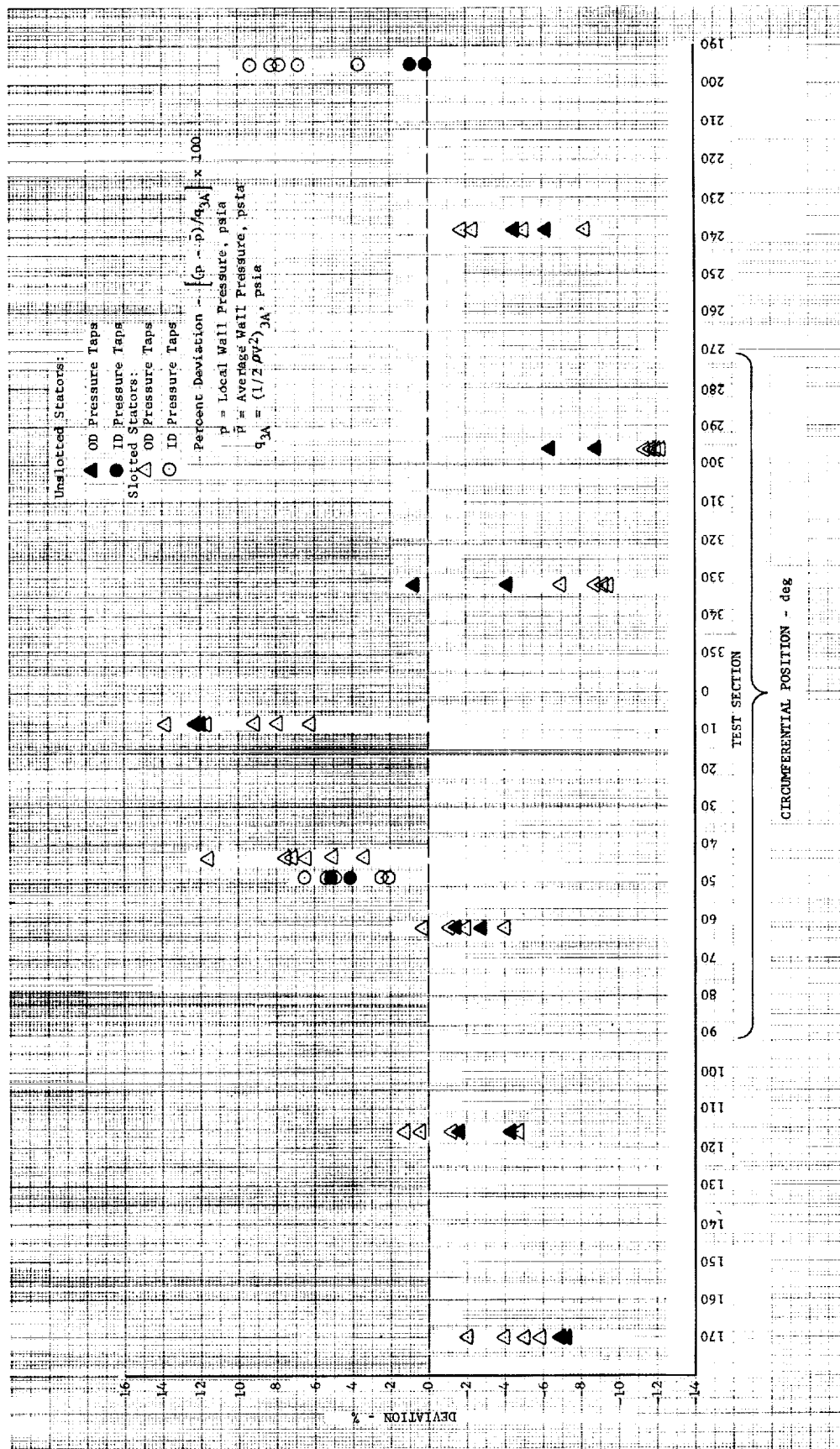


Figure IV-2. Circumferential Static Pressure Deviation at Station 3A (Rear Slot Configurations) DF 45539

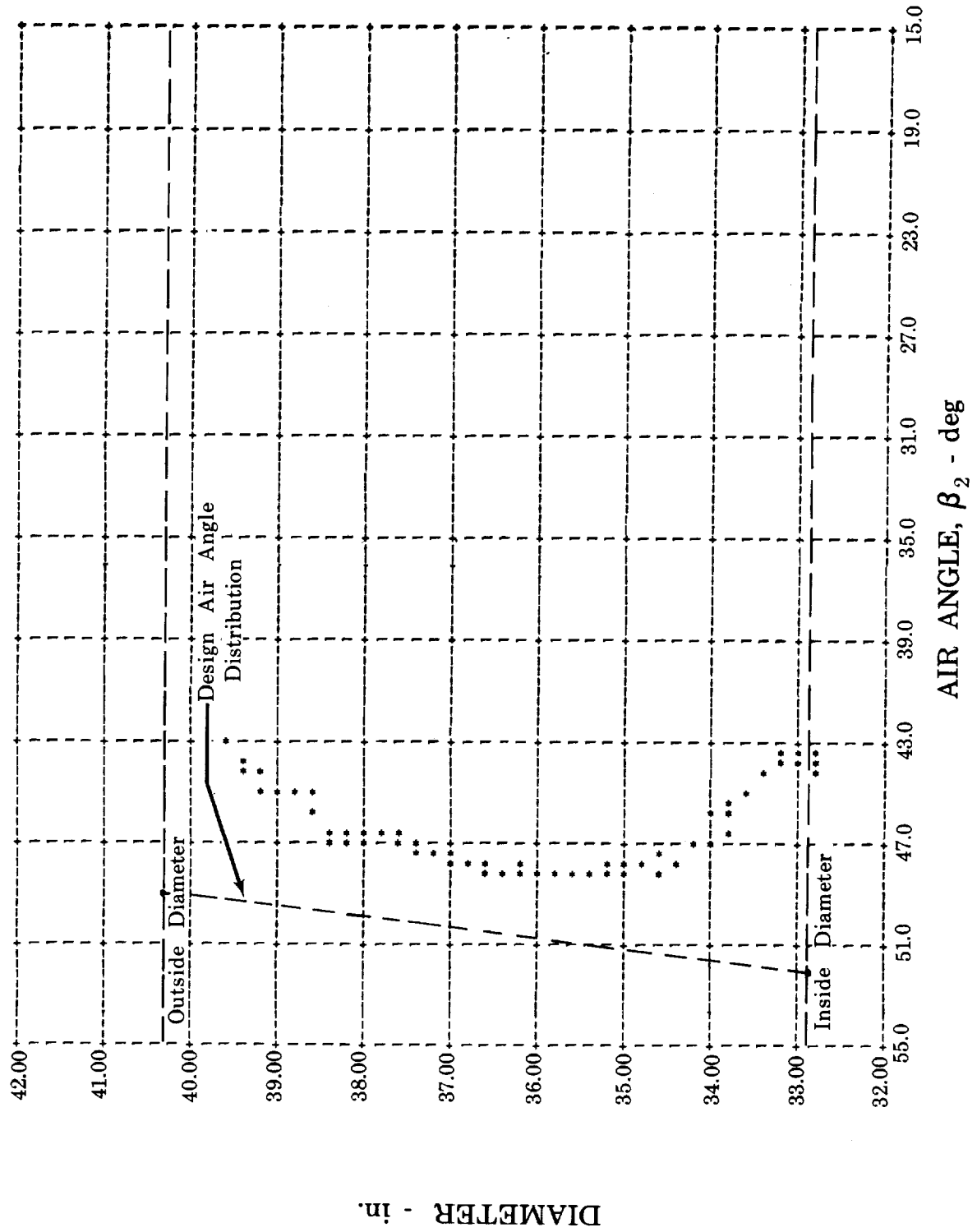


Figure V-1. IBM Plot of Stator Inlet Air Angle Profile, Configuration 1, Station 2

DF 45239

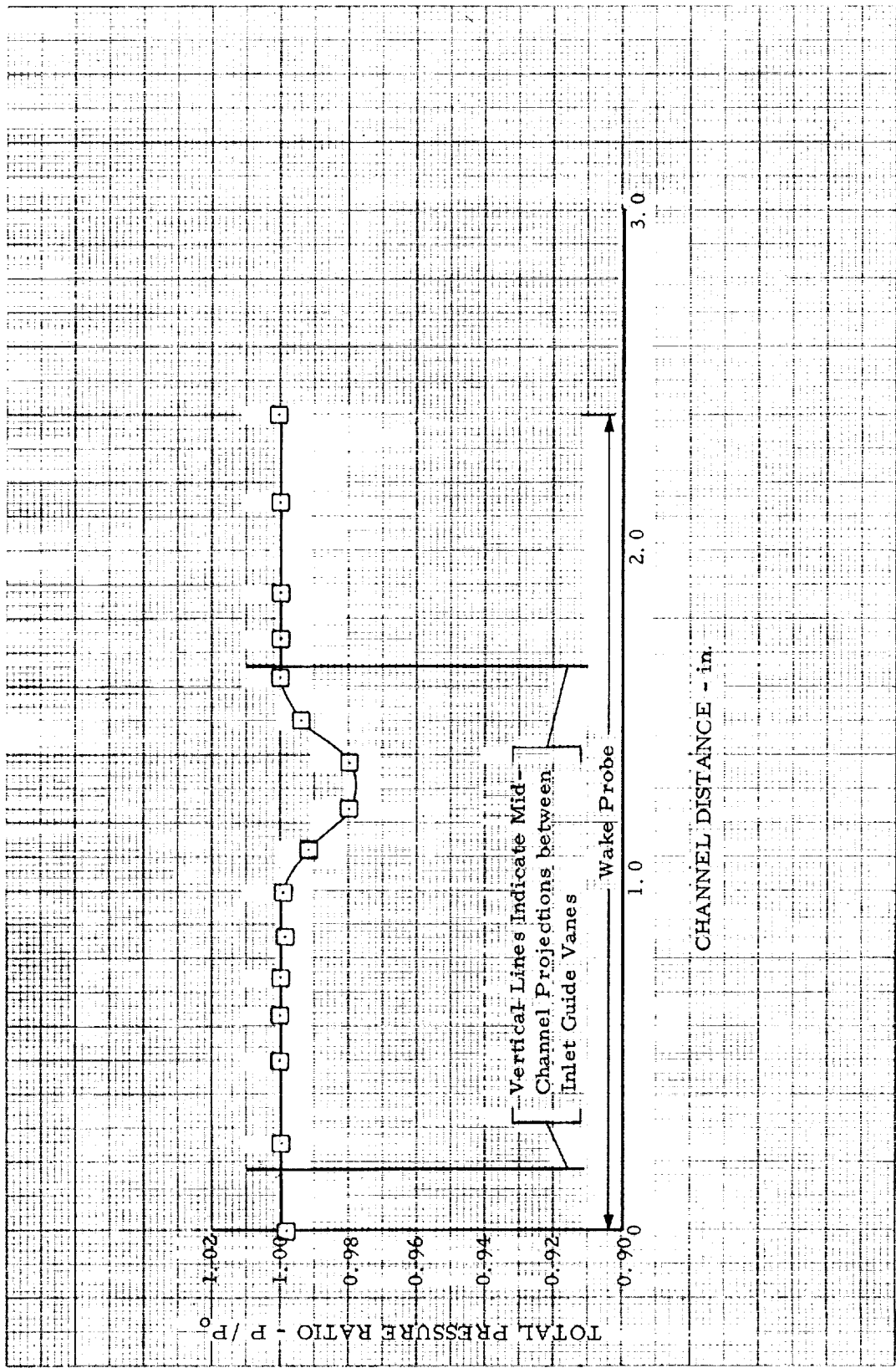


Figure V-2. Typical Inlet Guide Vane Wake Total Pressure Profile

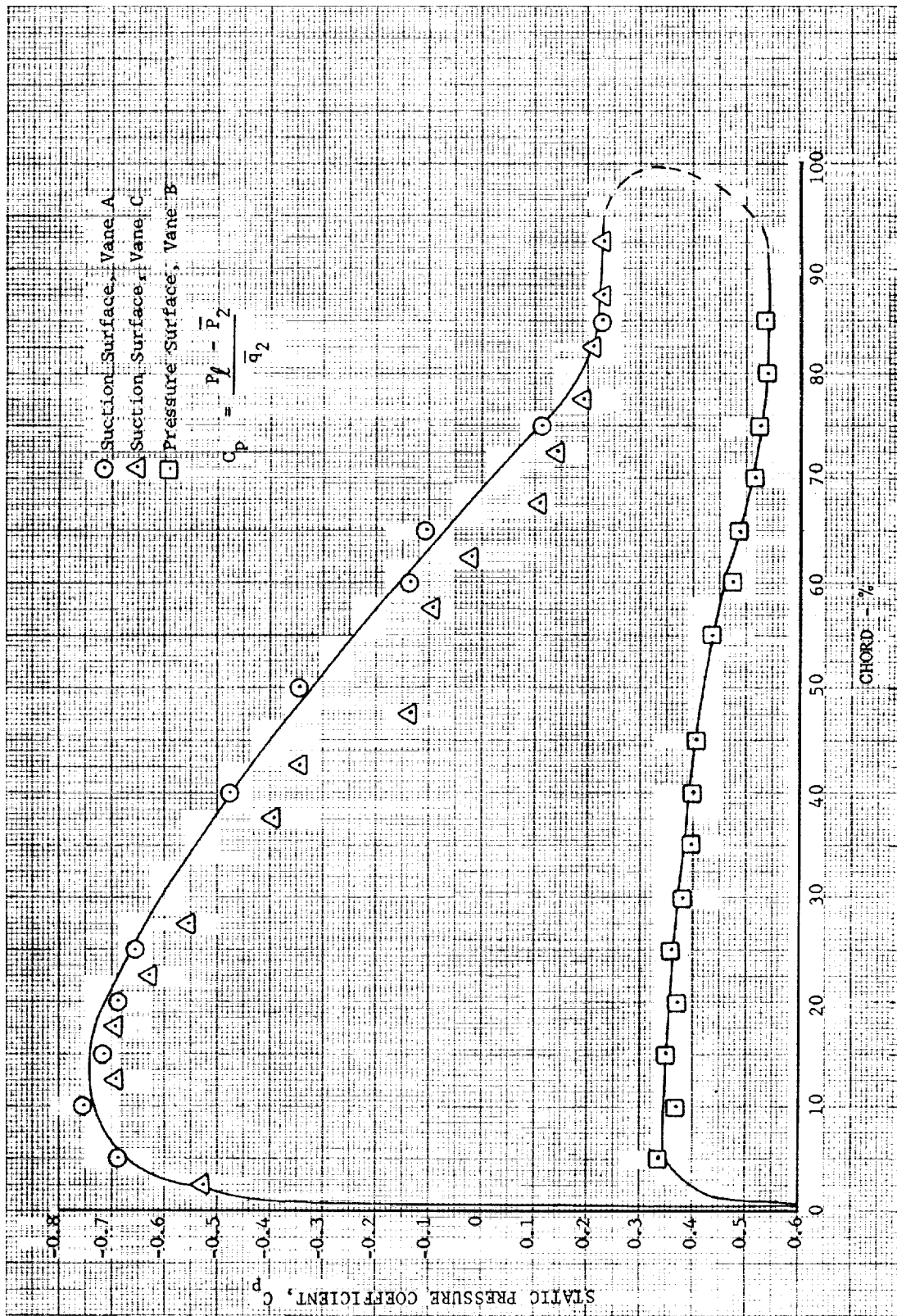
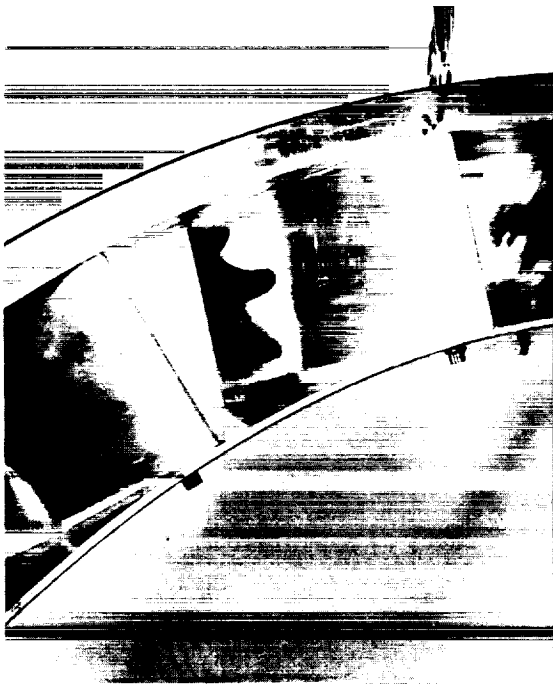


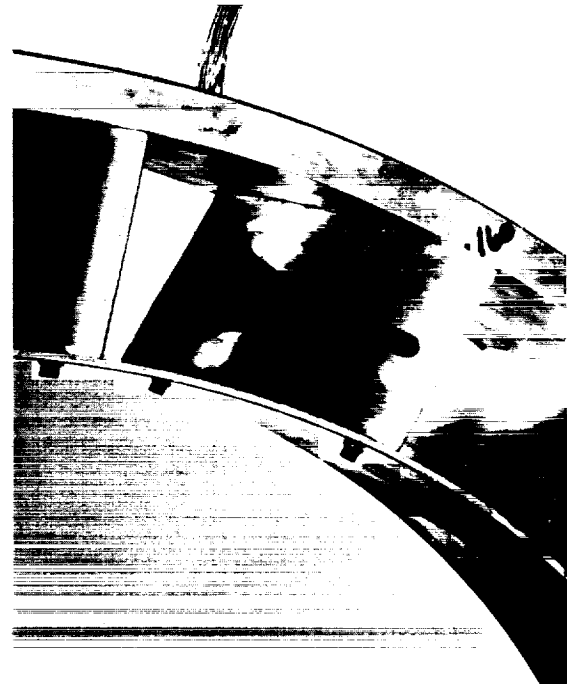
Figure V-3. Variation of Static Pressure Coefficient for Unslotted Stator Vane

DF 49844



Configuration 1  
Vane A

Dye Injected through Pressure Tap No. 12



Configuration 1  
Vane C

Dye Injected through Pressure Tap No. 21



Configuration 1A  
Vane C

Dye Injected through Pressure Tap No. 31

Figure V-4. Dye Injection Pattern, Unslotted  
Configuration

FD 15001A

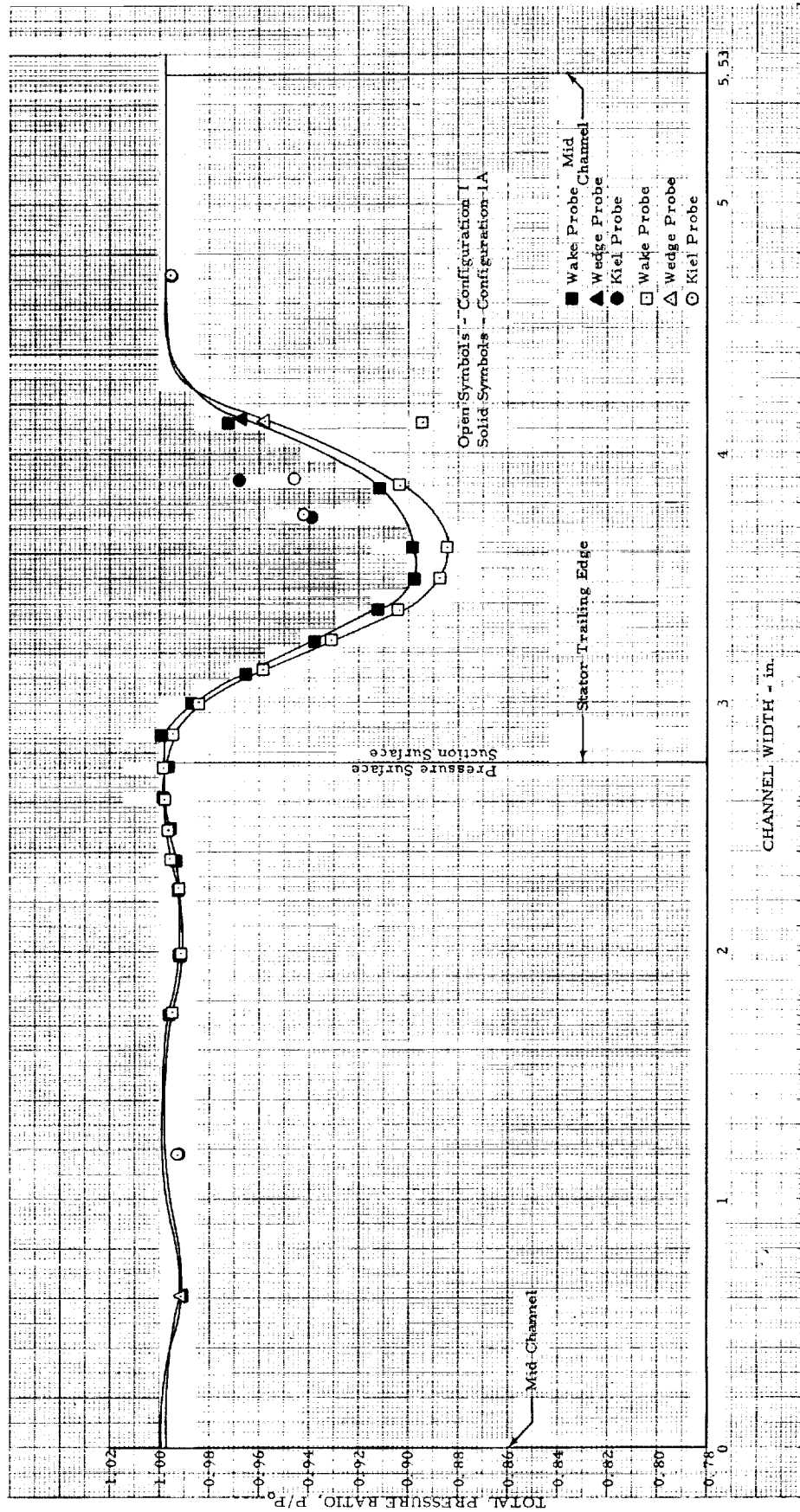


Figure V-5. Unslotted Stator Wake Total Pressure Profile

DF 49845

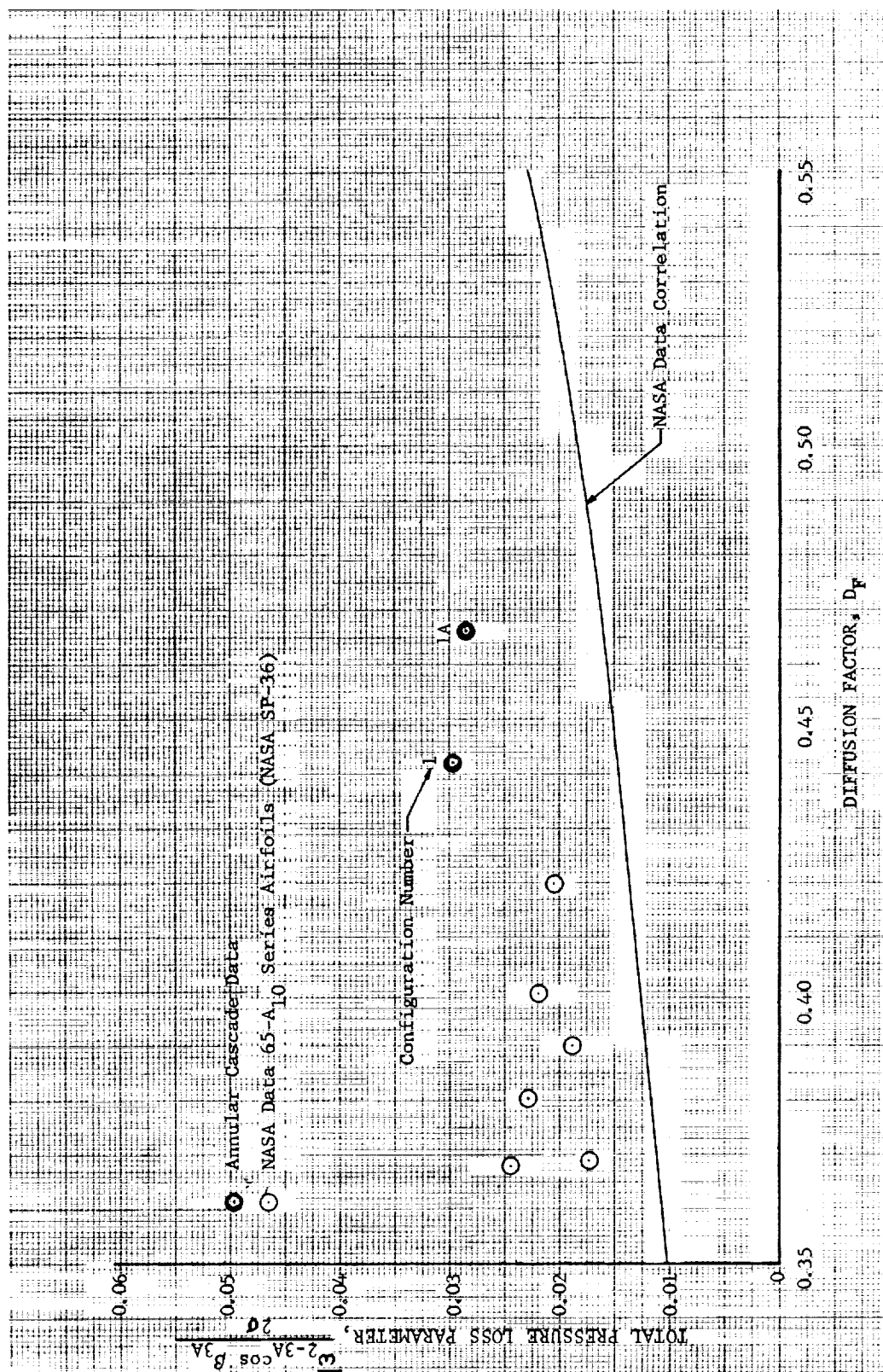


Figure V-6. Variation of Total Pressure Loss Parameter With Diffusion Factor (Unslotted Stators) DF 49846

FD 14679C

Configuration	$Y_2/Y_1$	$R_s$ in.	$r_1$ in.	$Y_1$ in.	$Y_2$ in.	Slot Location
1	Unslotted					
2	0.770	0.458	0.028	0.182	0.140	Forward
4	0.770	0.280	0.028	0.182	0.140	Rear
5	0.600	0.458	0.028	0.233	0.140	Forward
6	0.770	0.535	0.028	0.182	0.140	Rear
7	0.450	0.458	0.028	0.311	0.140	Forward
8	0.680	0.535	0.028	0.206	0.140	Rear
9	0.486	0.458	0.056	0.288	0.140	Forward
10	0.710	Curve	0.028	0.206	0.146	Rear
14	0.590	Curve	0.036	0.254	0.150	Rear
15	0.291	0.458	0.056	0.244	0.070	Forward
18	0.435	Curve	0.056	0.244	0.106	Forward

- R - Coanda Radius  
 $r_1$  - Slot Leading Edge Radius  
 $Y_1$  - Slot Capture Dimension  
 $Y_2$  - Slot Exit Dimension  
 $\psi$  - Angle Formed by Slot Centerline and Mean Camber Line  
 $R_p$  - Slot Pressure Surface Radius

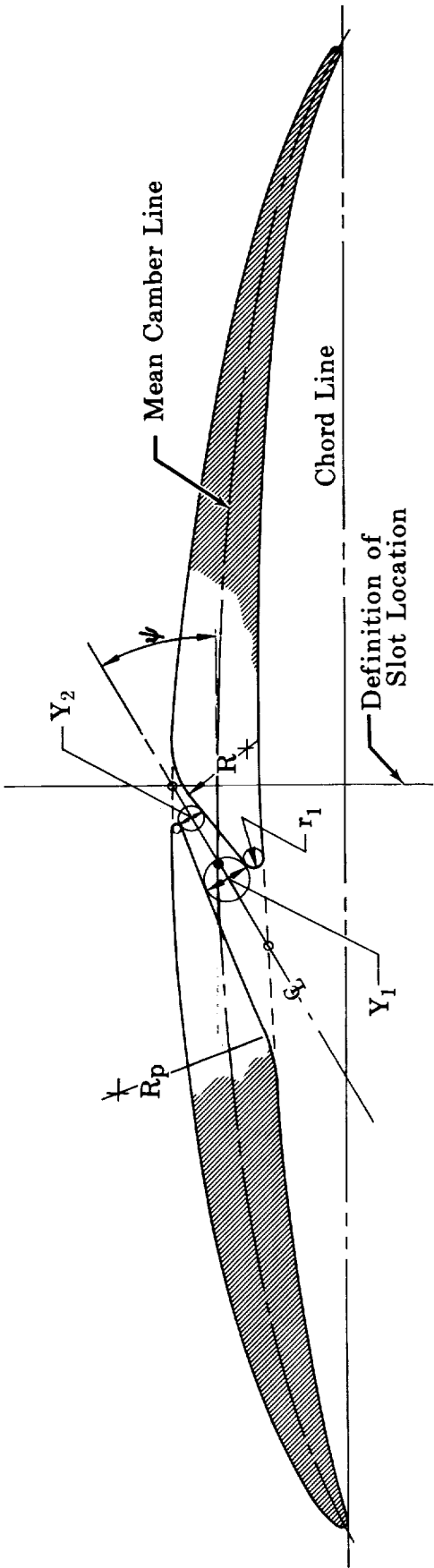


Figure V-7. Slot Geometry Nomenclature and Parameters



# 55% Chord Slot Location

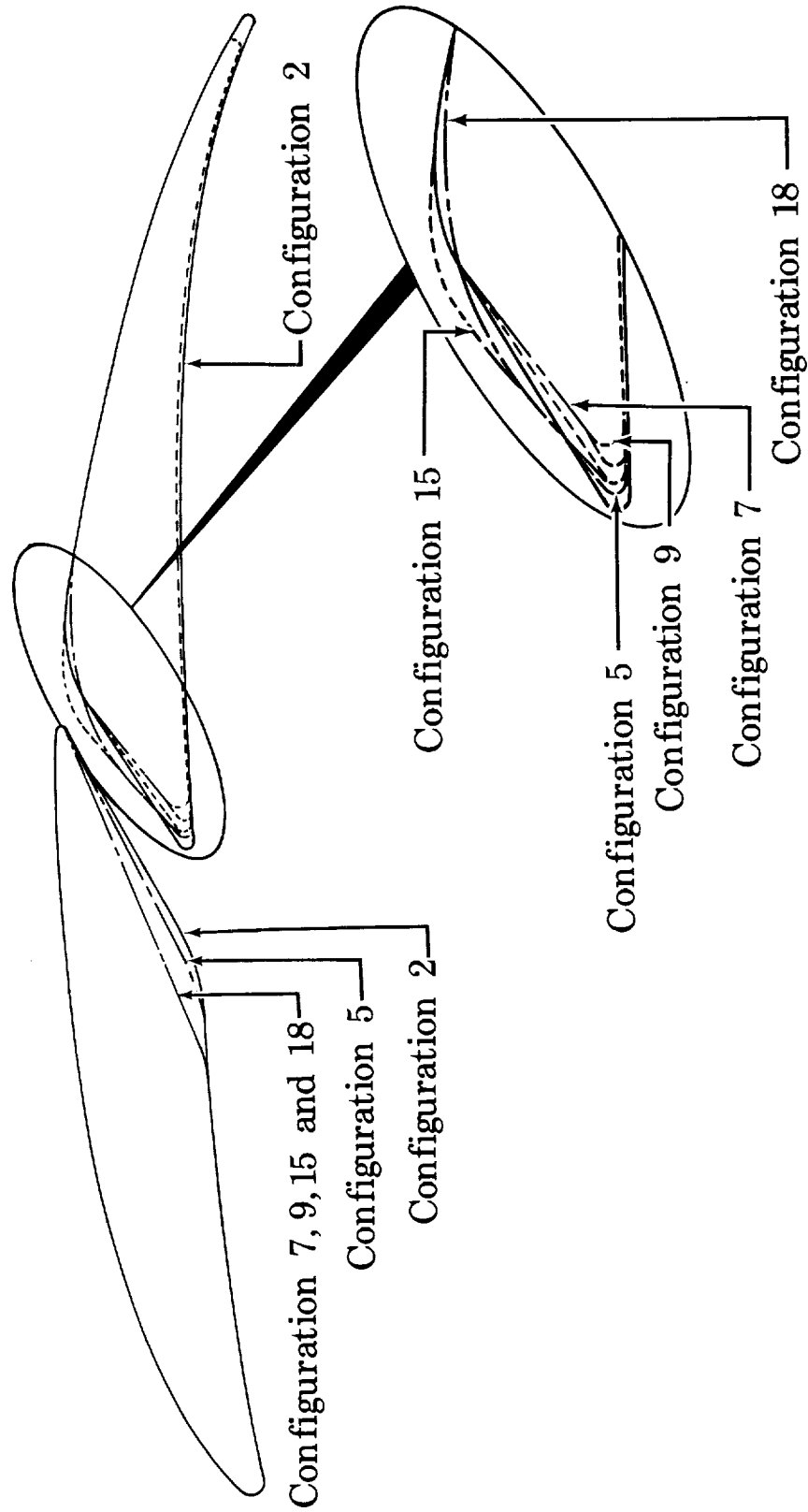


Figure V-8. Annular Cascade Stator Slot Configurations

### 75% Chord Slot Location

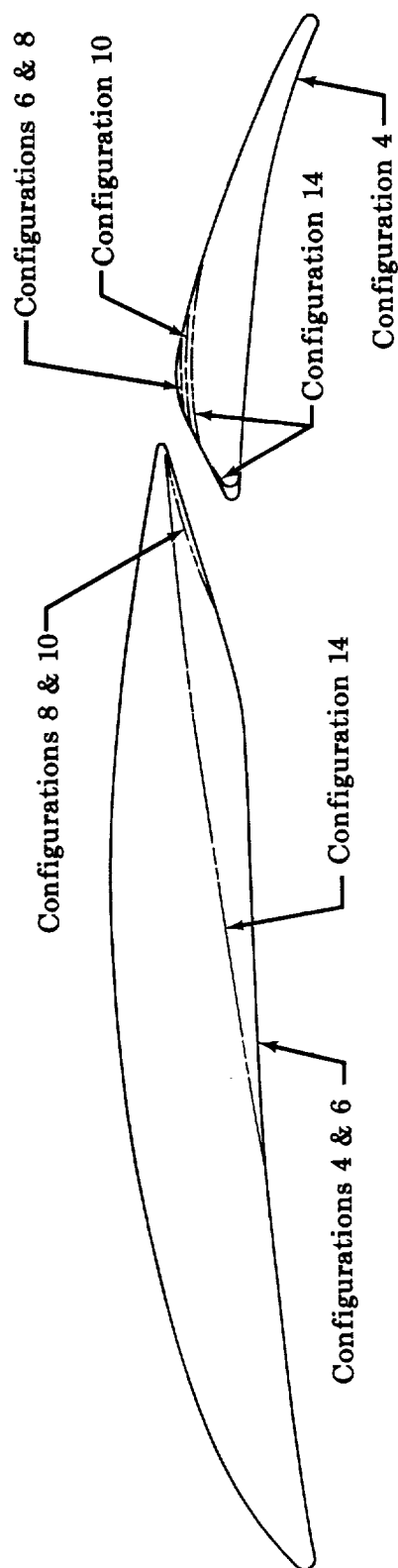


Figure V-9. Annular Cascade Stator Slot Configurations

FD 14677

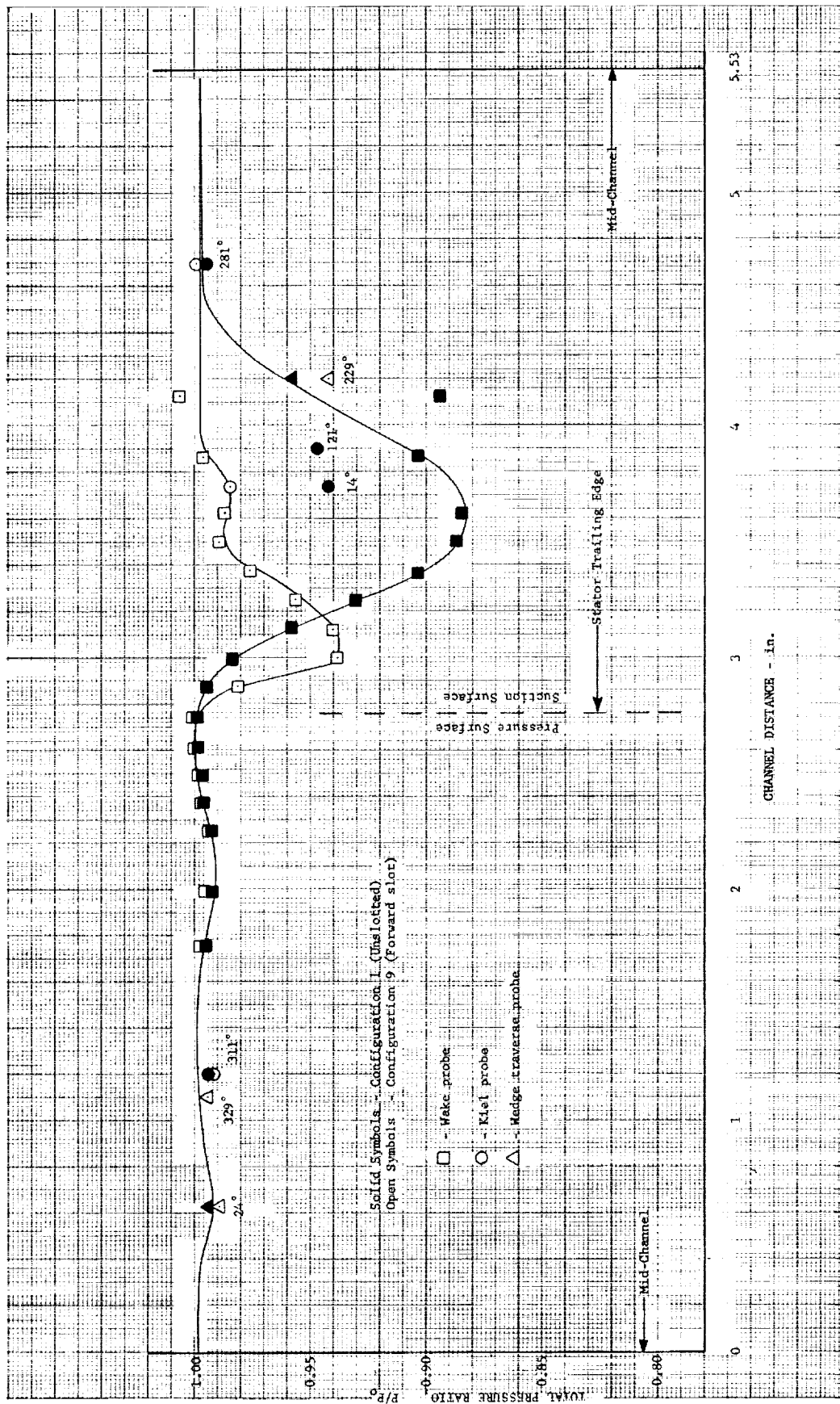


Figure V-10. Comparison Unslotted Stator Wake With Forward Slot Stator Wake

DF 45540

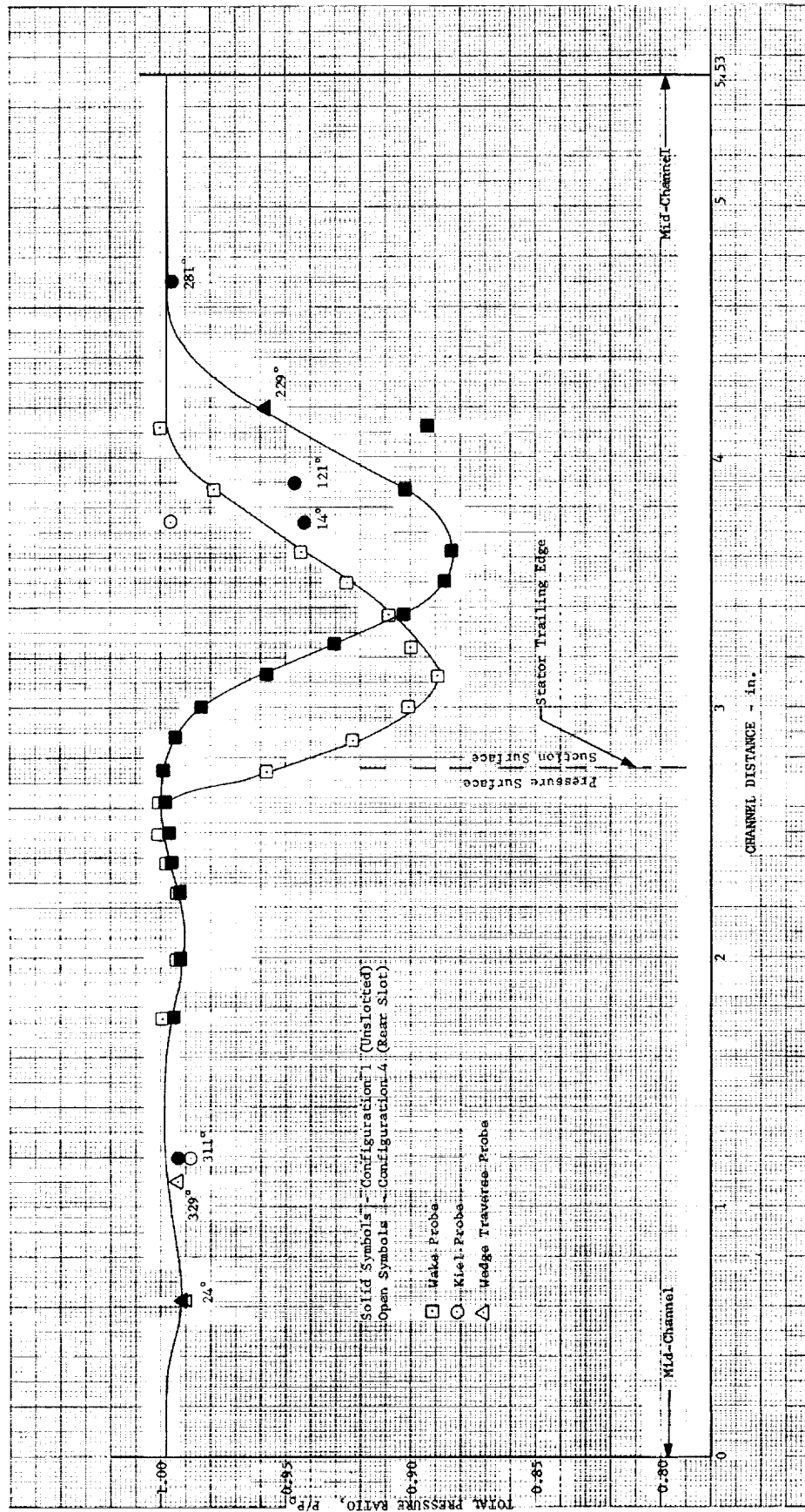


Figure V-11. Comparison of Unslotted Stator Wake With Rear Slot Stator Wake

DF 45541

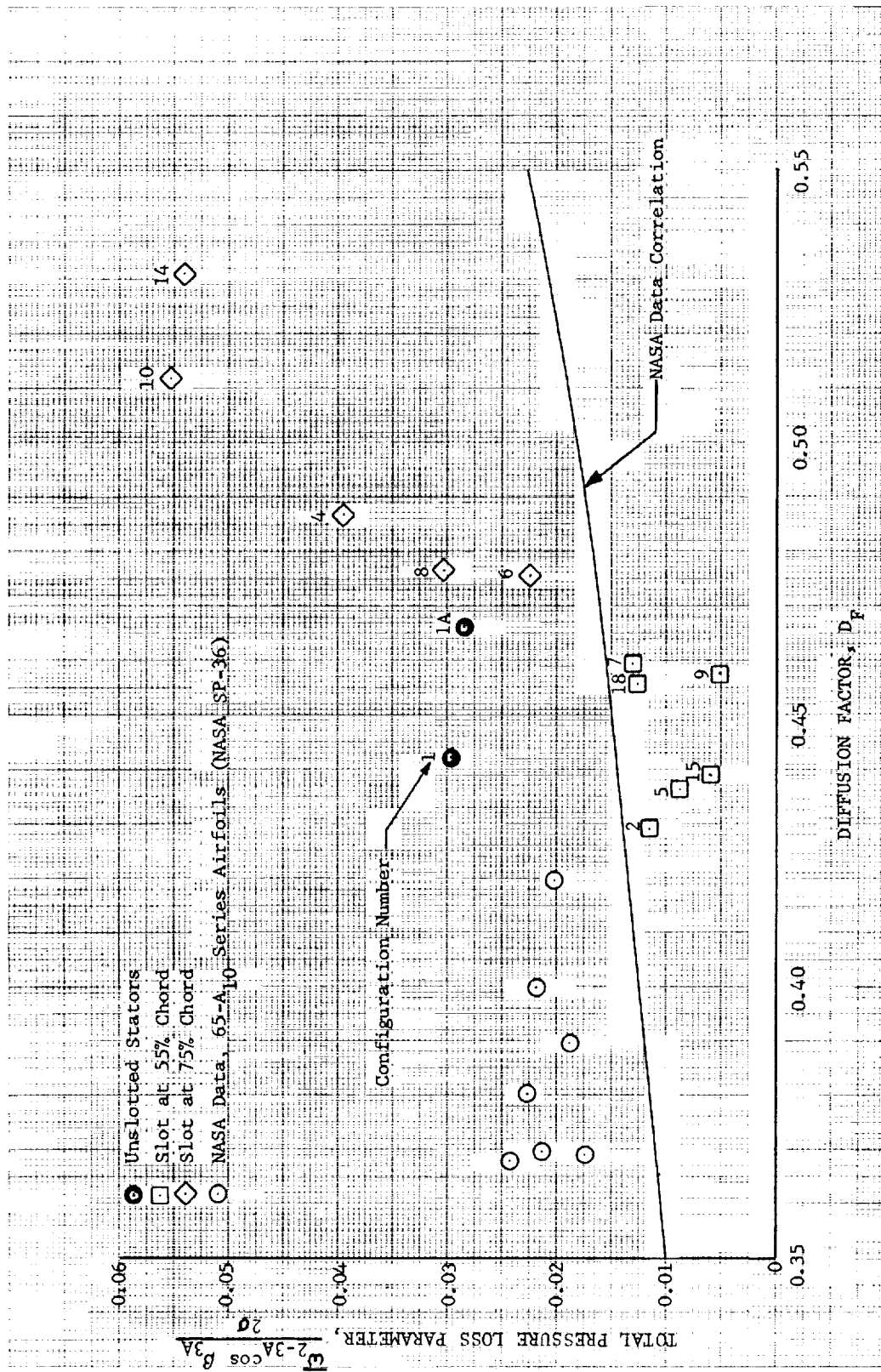


Figure V-12. Variation of Total Pressure Loss Parameter With Diffusion Factor (All Configurations) DF 49847

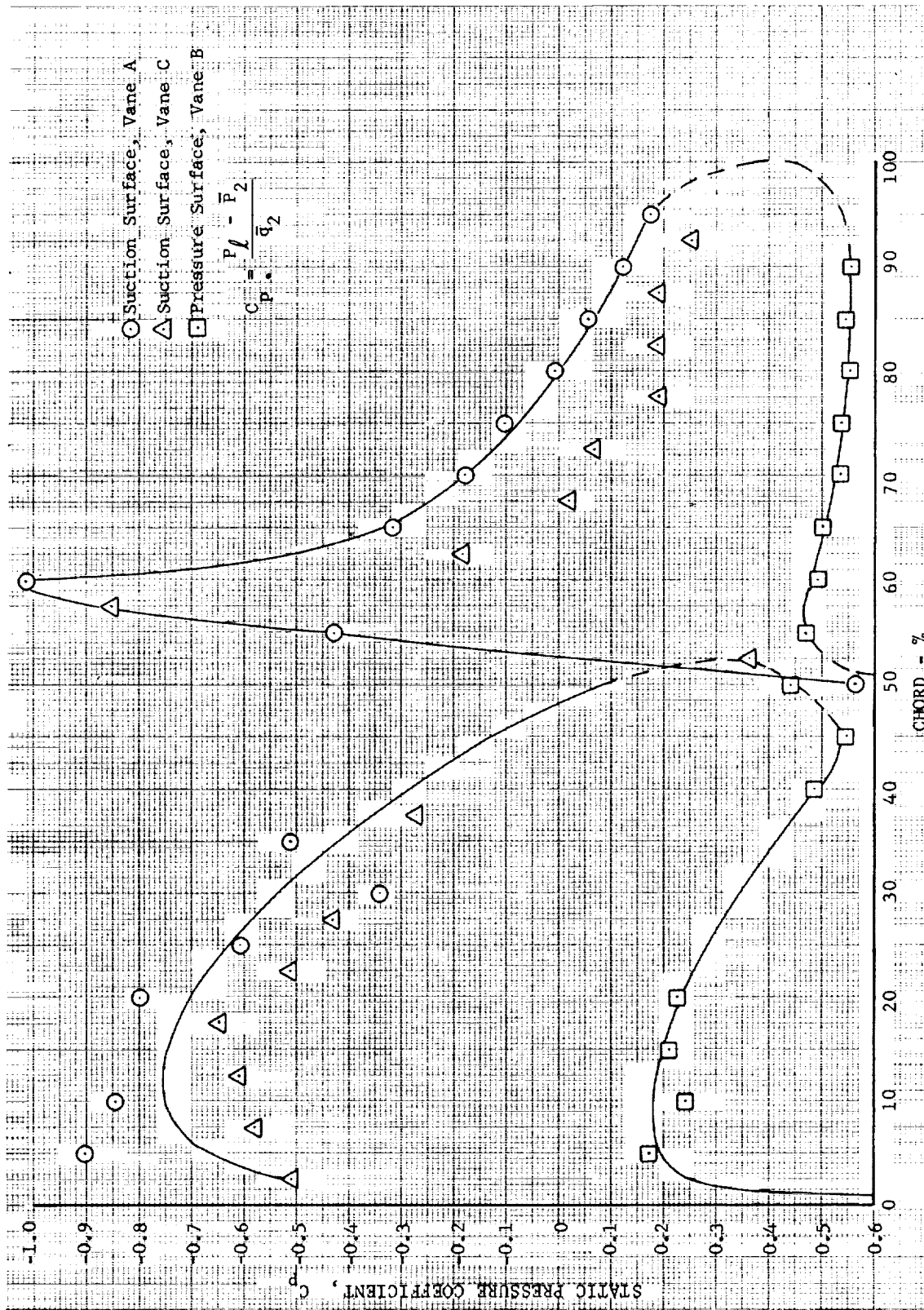


Figure V-13. Variation of Static Pressure Coefficient for Slotted Stator (Configuration 9)

DF 49848

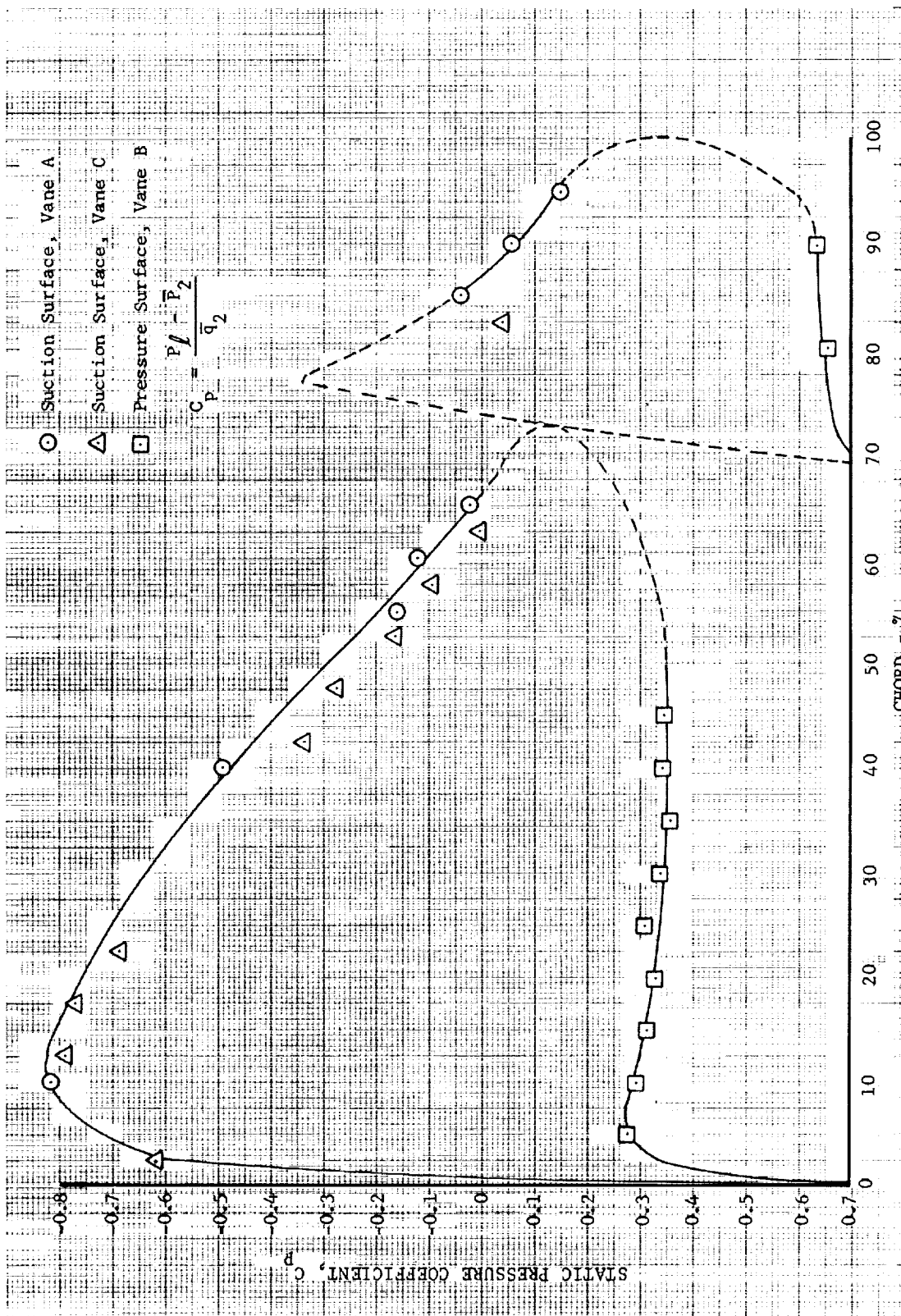


Figure V-14. Variation of Static Pressure Coefficient for Slotted Stator (Configuration 4)

DF 49870

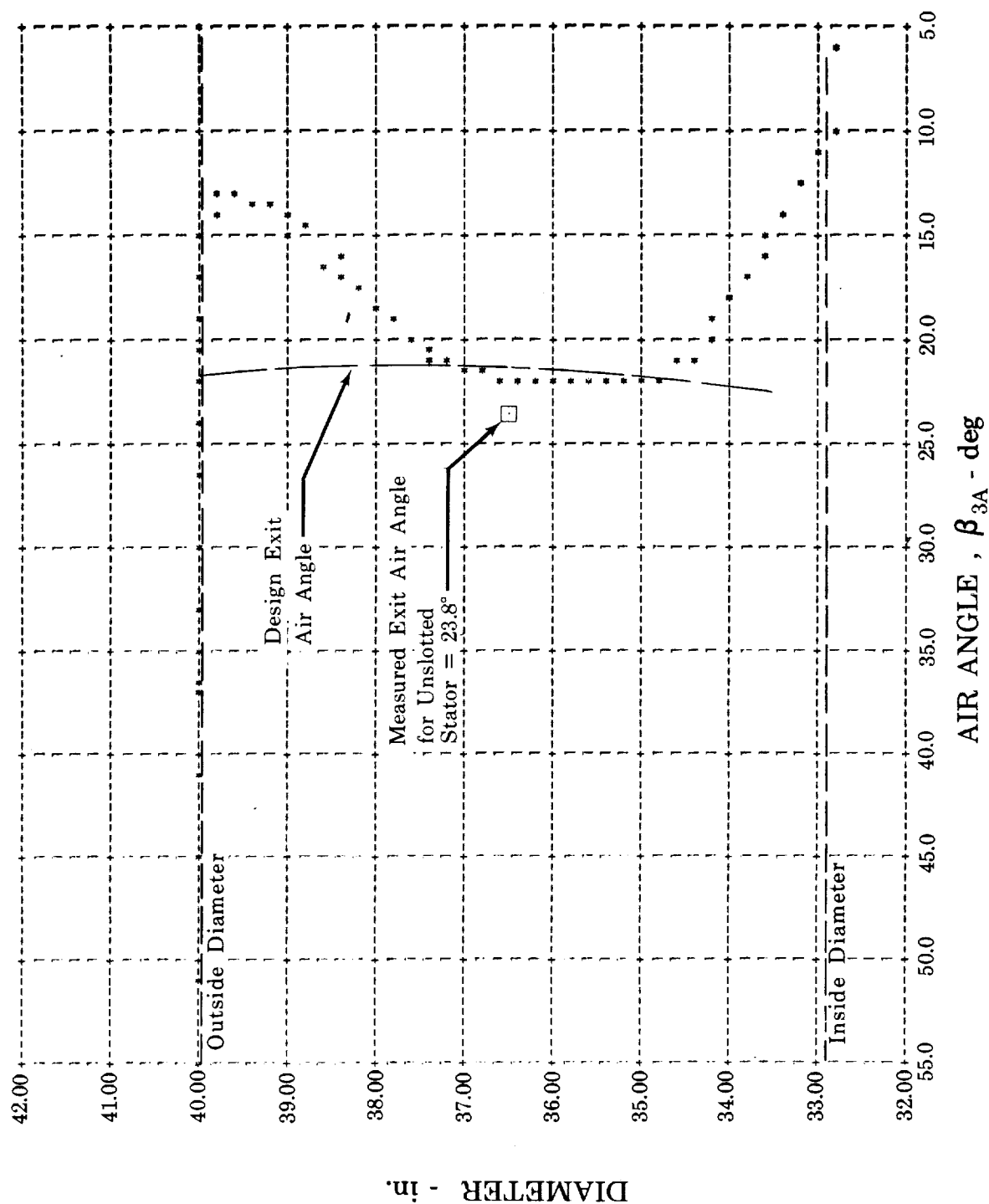


Figure V-15. IBM Plot of Stator Exit Air Angle Profile, Configuration 9, Station 3A

FD 17443A